THE ENGINEER

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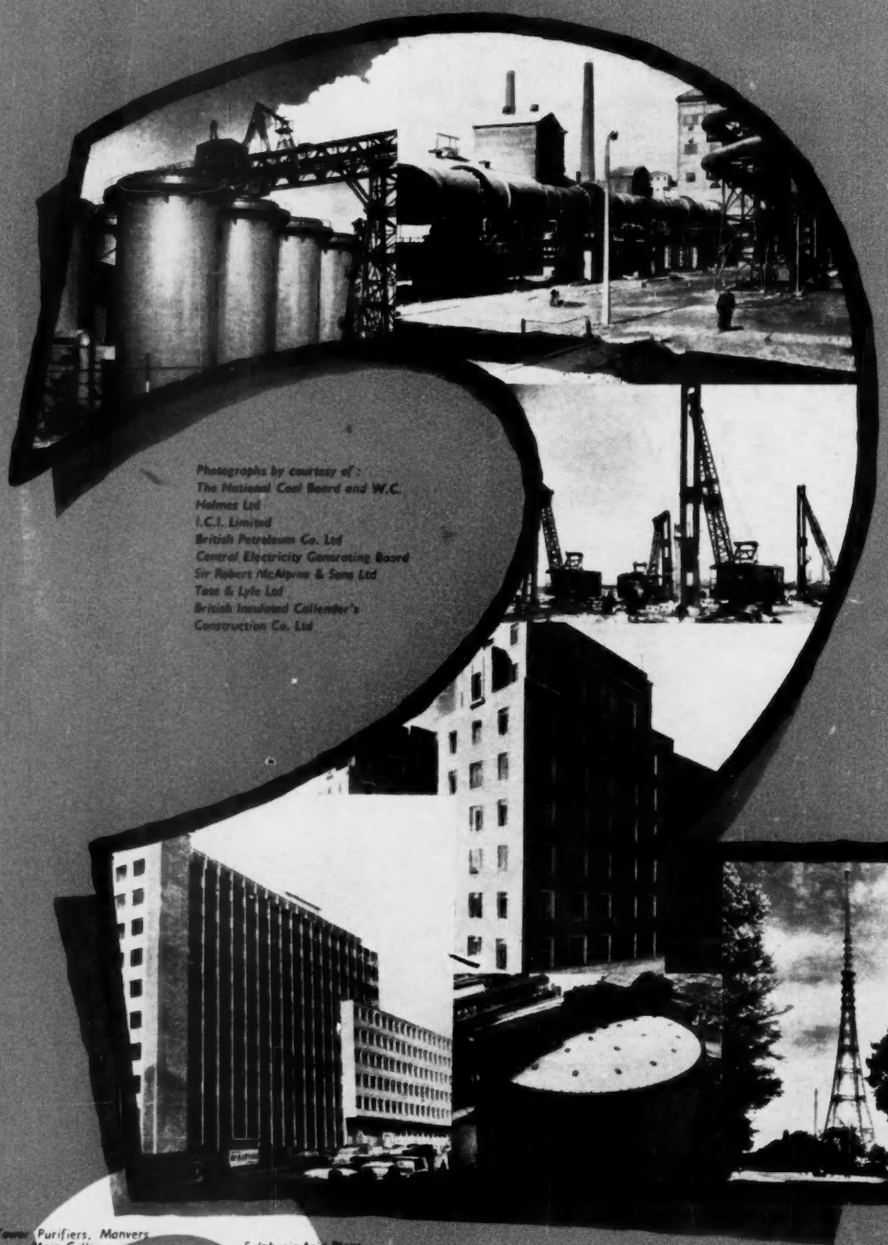

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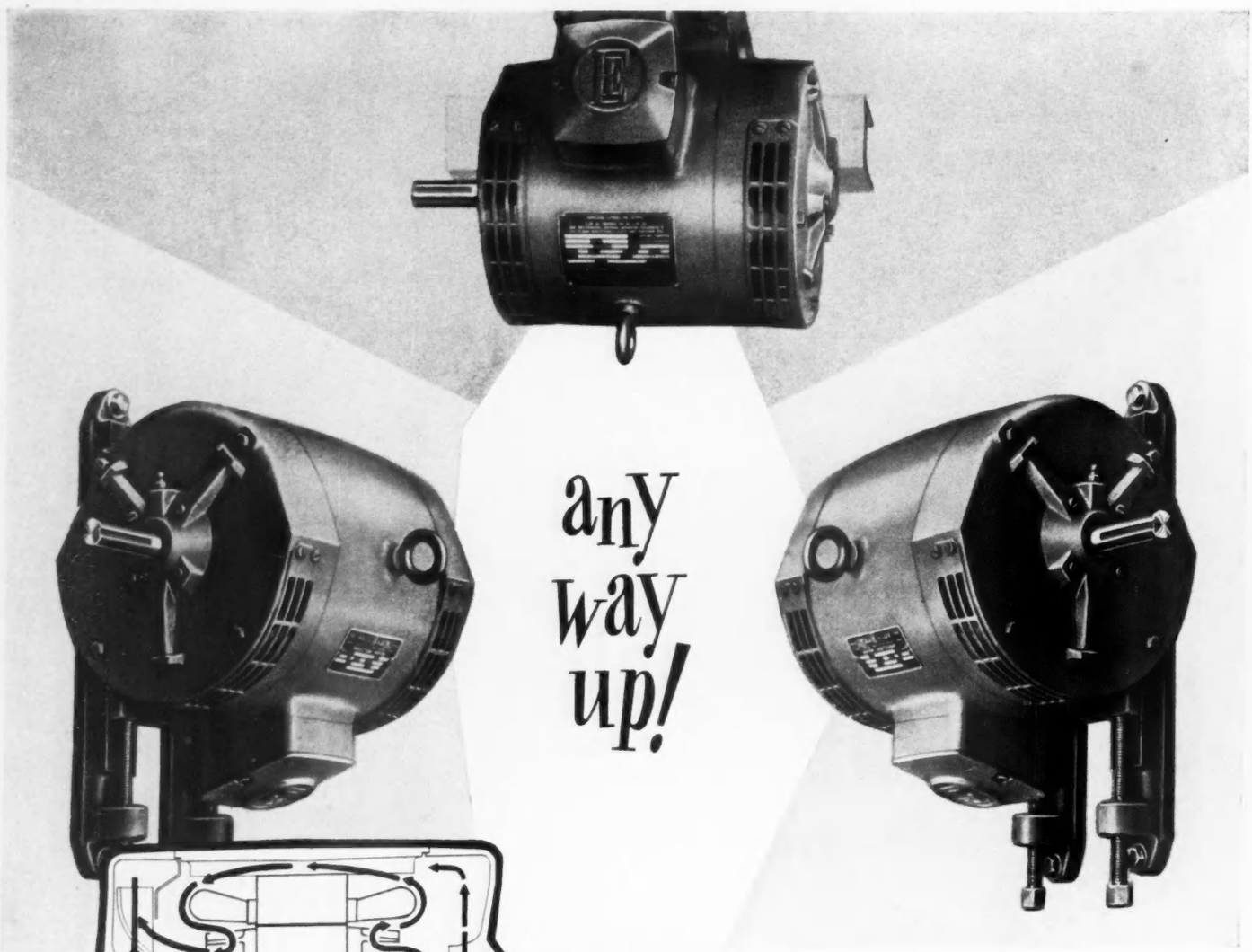

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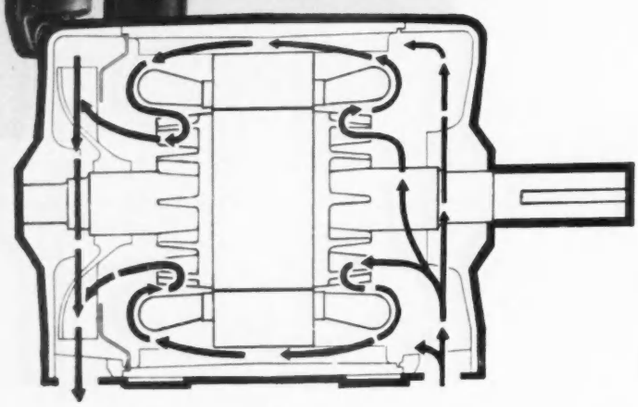

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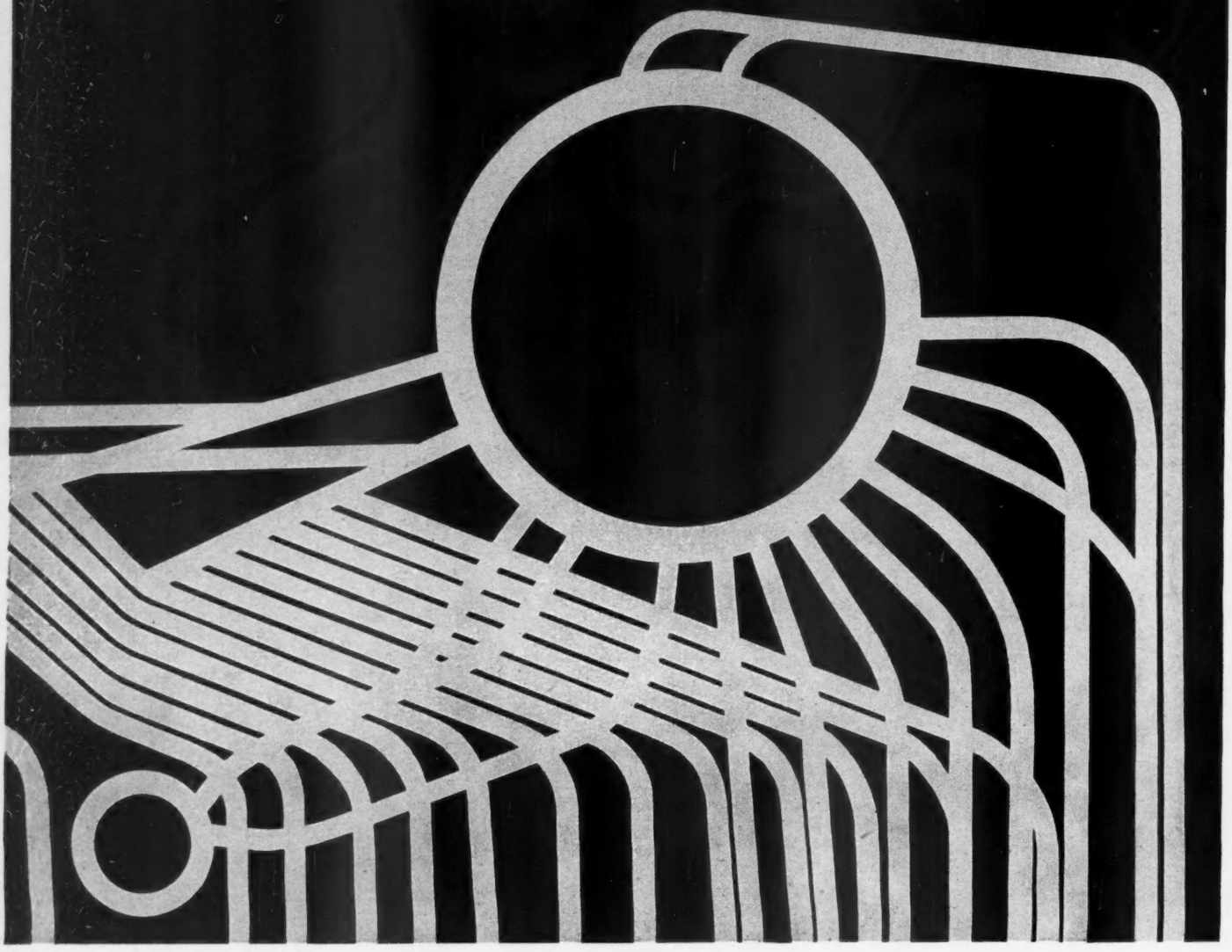

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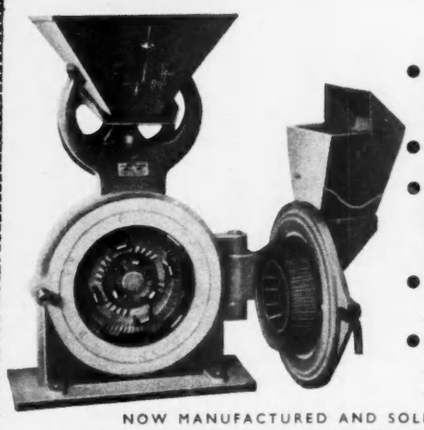

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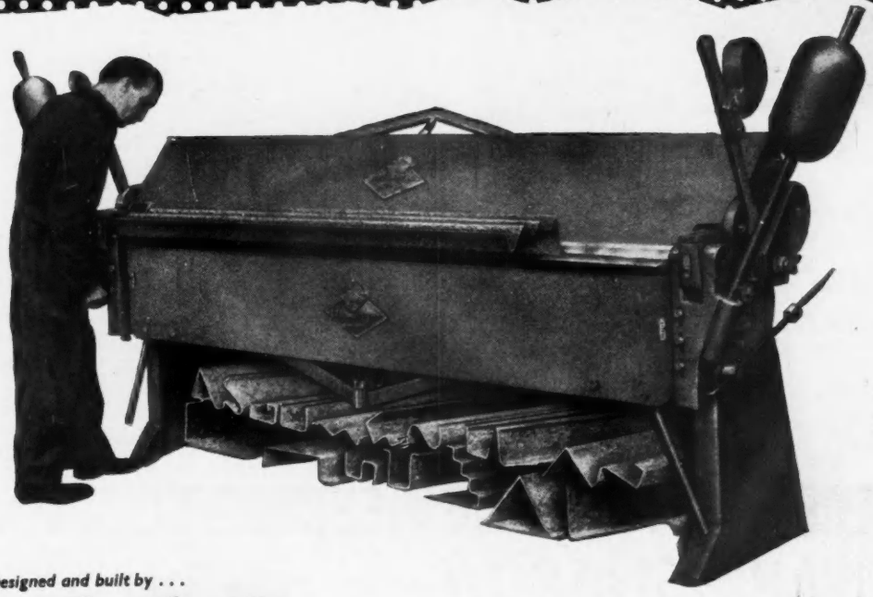

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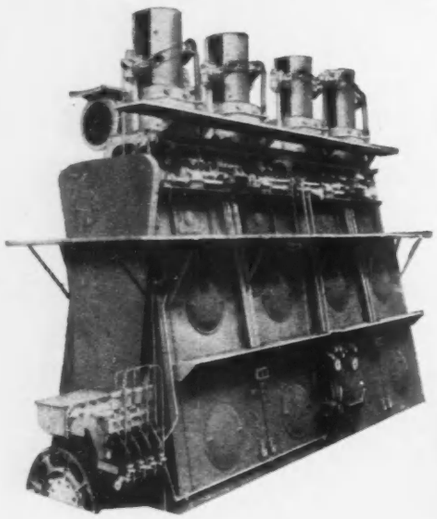

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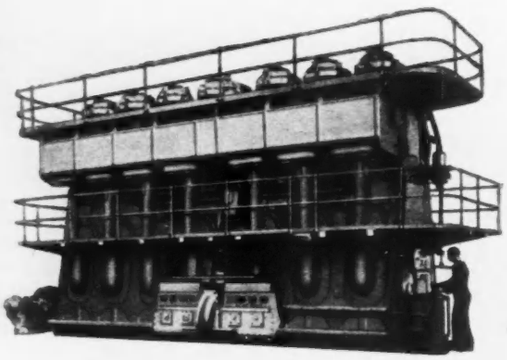

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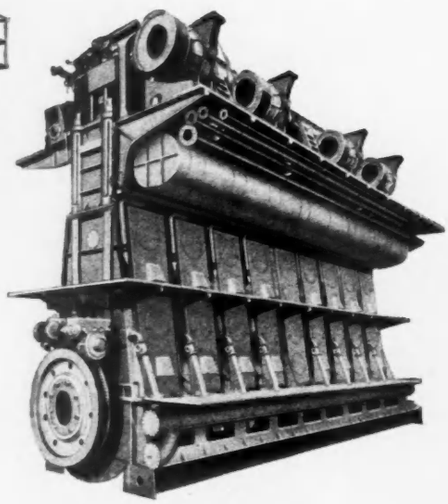

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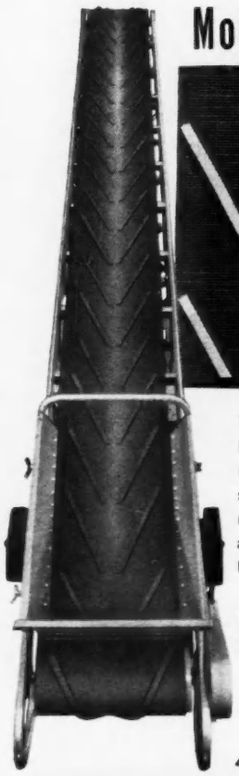

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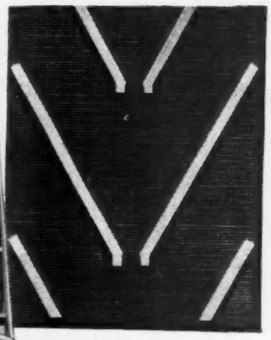

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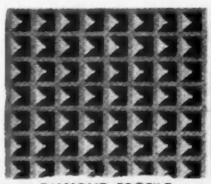
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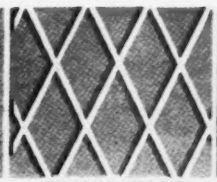
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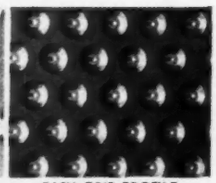
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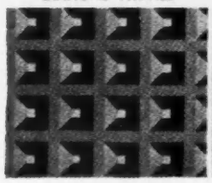
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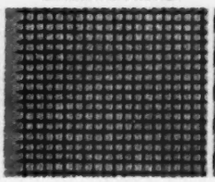
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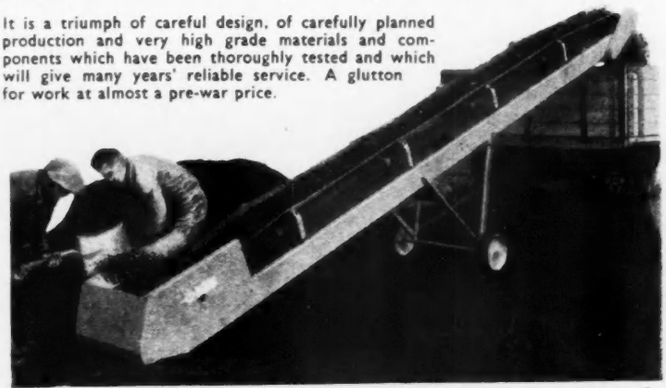

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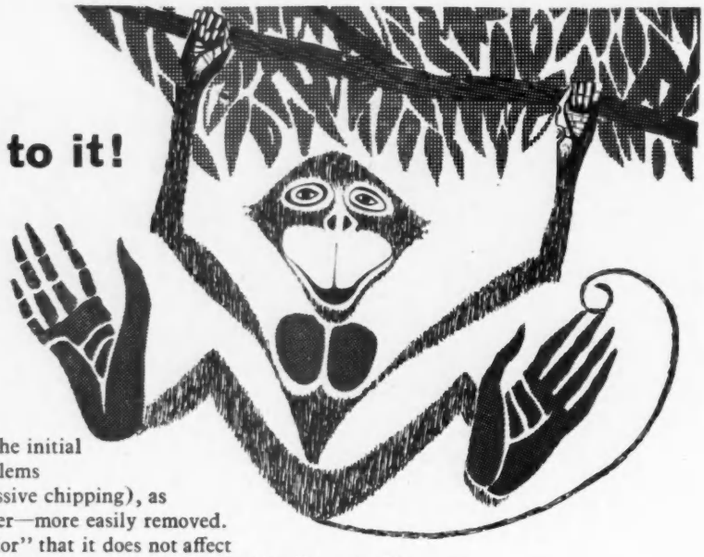

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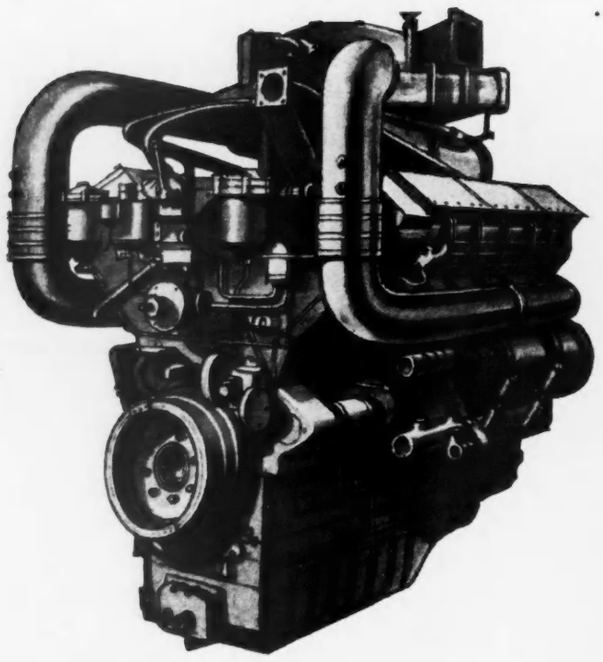
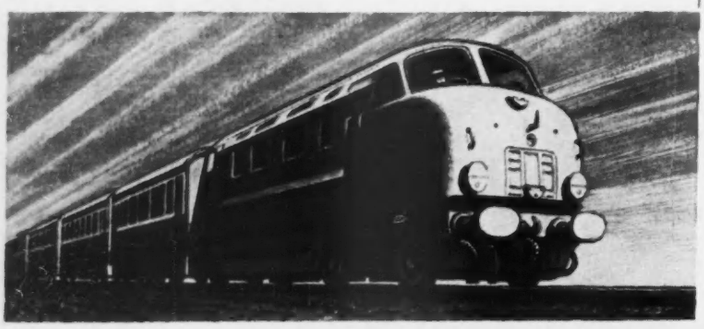


Typical of the MD range of engines is this Type 650 12 cylinder supercharged model with cylinders arranged in 'V' formation.



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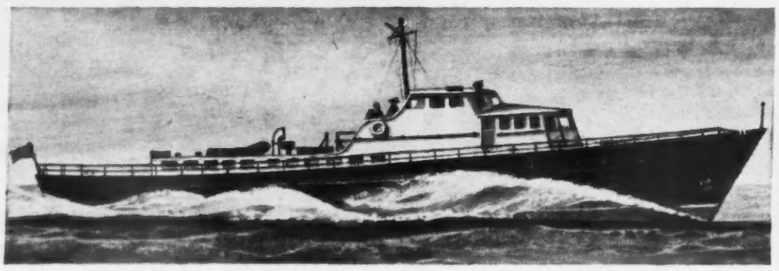

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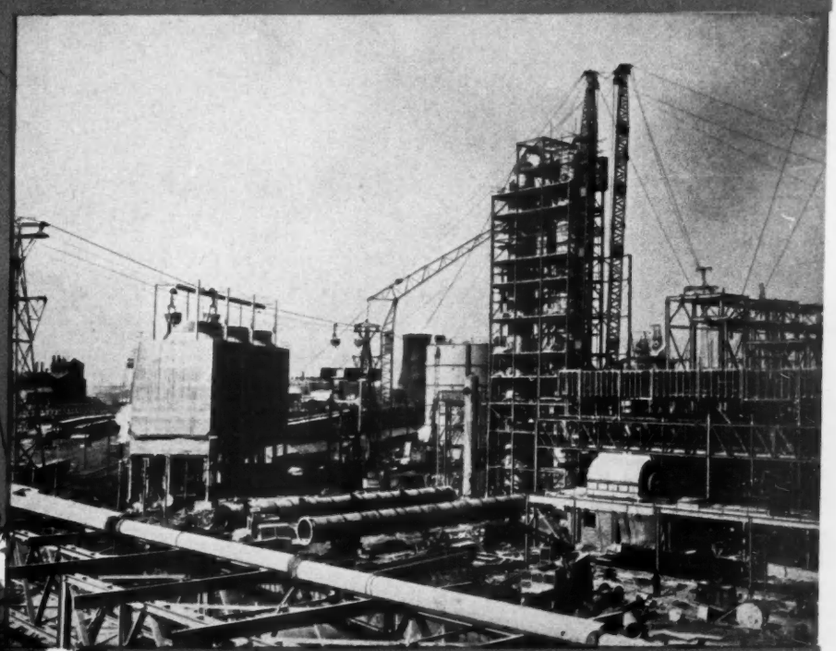

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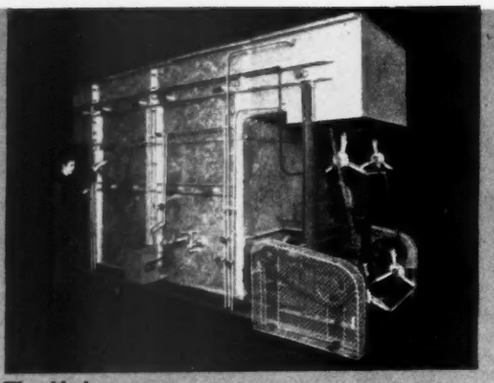
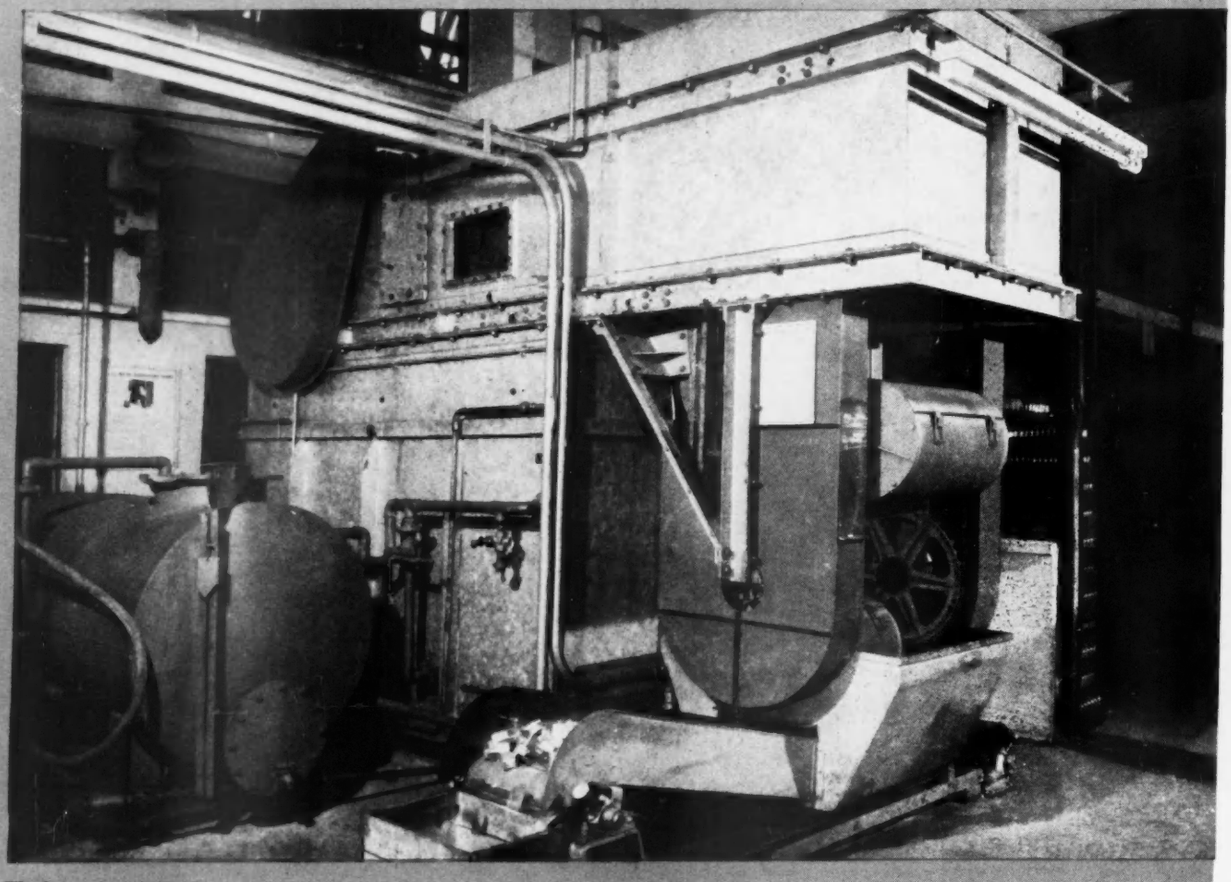
1938 I.C.I. supplied John Dale Ltd. with a mechanised trichloroethylene degreasing plant, to give cold liquor and hot vapour treatment, for cleaning light aluminium impact extruded containers. Work baskets were fed through the plant on a double chain conveyor (see illustration).



The old plant

One good plant sells another



The later plant in service

1957 I.C.I. supplied a second plant, similar to the first, but giving boiling liquor instead of cold liquor treatment. Heating is by a choice of steam or electricity. An interconnected still purifies the solvent. Baskets are now emptied and recharged in about 30 seconds. The hourly throughput is from 35-40 basket loads, each holding some 4 cu. ft. of containers.

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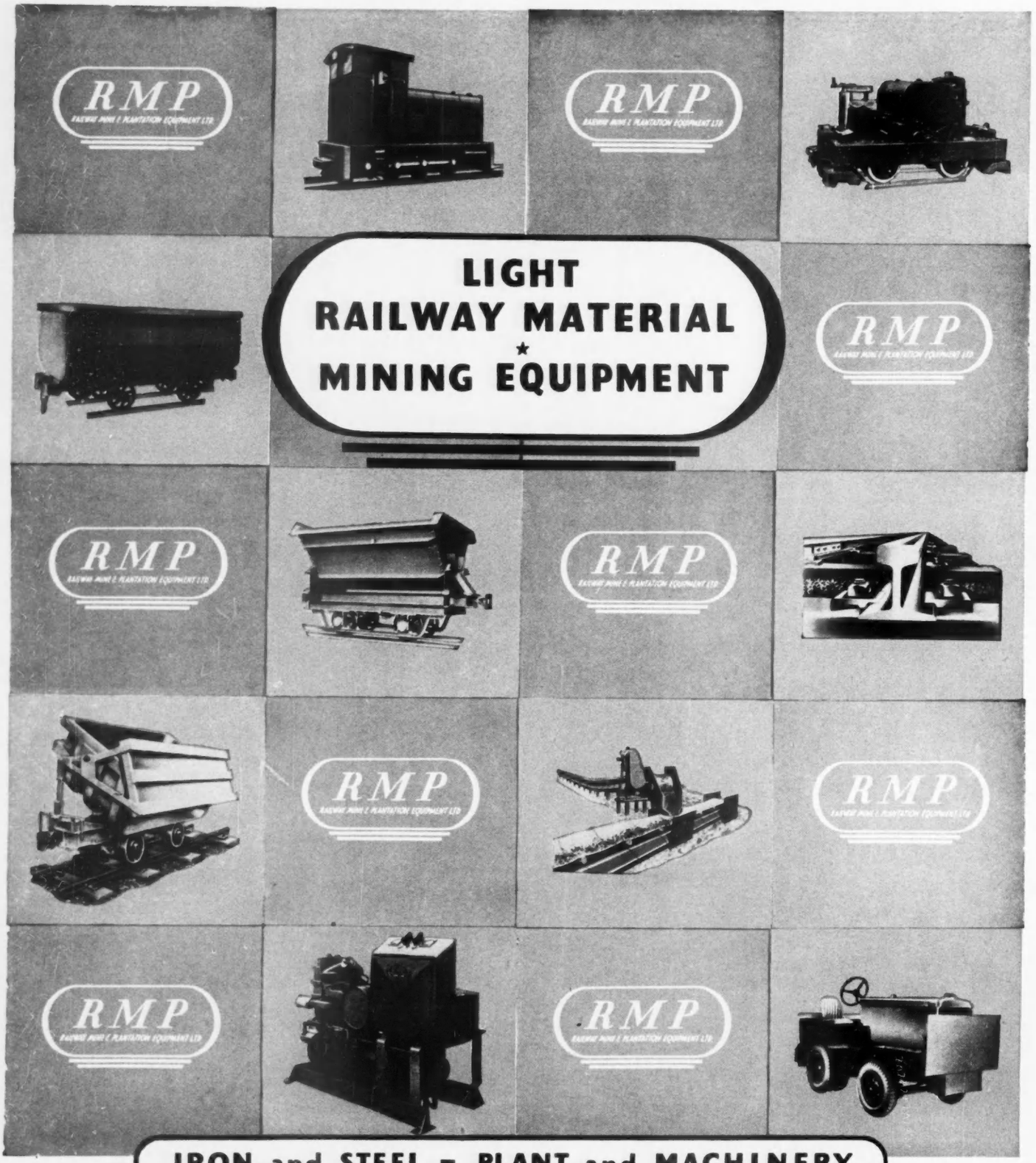

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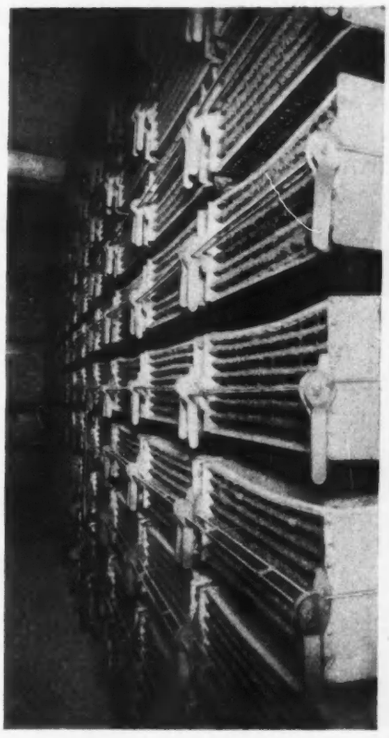

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tested in accordance with

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Against Aloxite 50—95% **Against Aloxite 225—93%**

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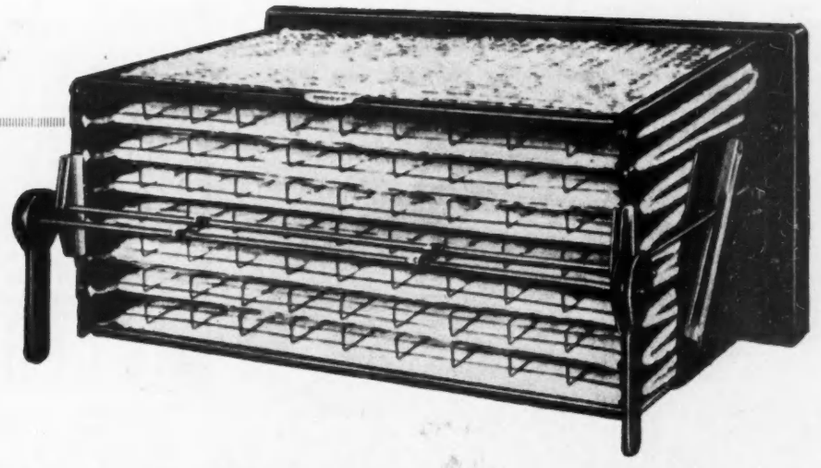

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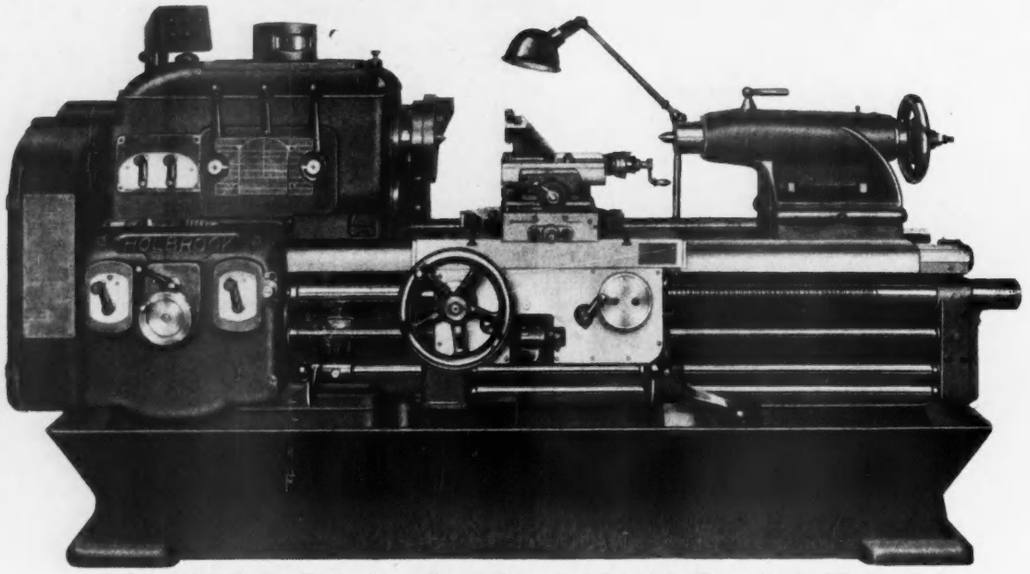

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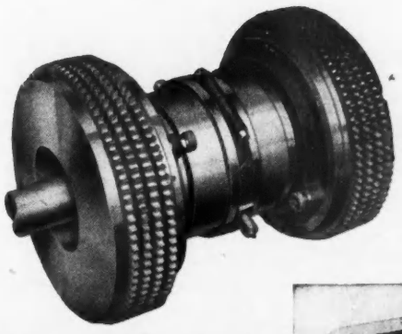

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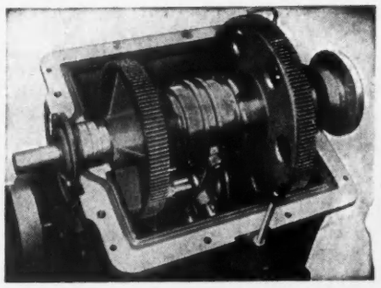
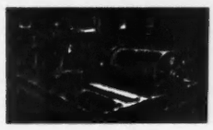
Multiple Disc CLUTCHES

Resiliency, sensitivity, ease of control and the ability to perform continuous heavy duty without frequent adjustment, make Taylor Multiple Disc Clutches a popular choice for machine tool, plant, civil and heavy engineering. Such characteristics are ensured by:—Heat treatment and total enclosure of all operating parts; positive locking; single point adjustment and precision manufacture on modern plant. A Taylor Clutch is a self-contained unit, easily assembled, quickly fitted and produced to perform many years of strenuous work.





The illustrations show a typical application. The Reid Gear Co., Ltd., required a powerful, sensitive and completely trustworthy clutch unit for their two-speed reduction gear, to transmit the enormous effort applied in actuating the emergency sluice gate on a Scottish Hydro-Electric Project. The features mentioned above qualify Taylor Clutches to satisfy such exacting demands because they constitute the very ingredients of strength and reliability—the choice was a Taylor Multiple Disc Clutch.

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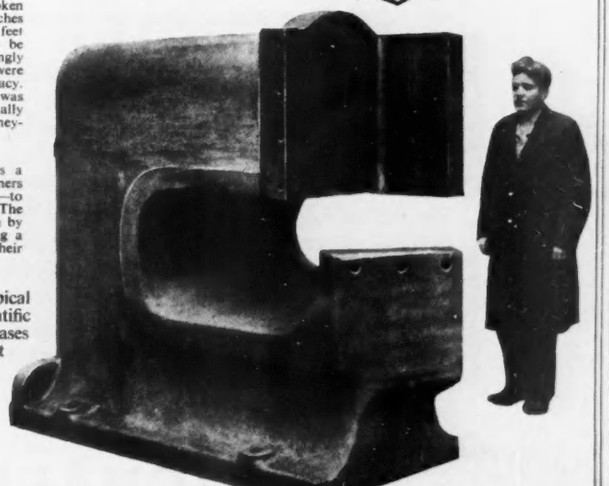
The owners of a big shearing machine were faced with a critical situation when the 4-ton body of this machine was broken in two places. They had two alternatives—should they (1) Sanction the expense of a new machine or (2) Ask Barimar to repair the broken body of the present one ? The firm decided on the sensible thing—Barimar was asked to put the casting right again. This was done " in double-quick time and at far less expense."

The damage was extensive, as the illustration shows ; two large pieces were broken away, and the metal was up to 4 inches thick. The fractures were several feet long, and the broken pieces had to be replaced exactly in position, strongly welded. Various parts of the casting were also re-machined with great accuracy. The welding completed, the casting was rigorously tested for strength, and finally tagged with the famous Barimar Money-back Guarantee.

The repair was urgent, for this was a " key " machine employed by the owners —a firm of iron and steel merchants—to cut large sections of metal to size. The repaired casting was returned to them by Barimar in record time, thus avoiding a serious hold-up in the deliveries of their steel orders.

This four-ton job is a typical example of the Barimar Scientific Welding Repairs Service. In cases where it is difficult to transport damaged machinery, Barimar Flying Squads will tackle repairs on the site, any time, anywhere—reducing hold-ups to the minimum.



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STANDARD POWERED WINCHES

for Direct Loads ranging from ½ ton to 7 tons

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Once it was thought impracticable to evolve a standard range of winches of this type, but now Richard C. Gibbins & Co. Ltd. have developed such a standard range—covering direct loads of 10 cwts. to 7 tons, and catering for mean rope speeds from 10 to 300 feet per minute.

An example of the economies effected by standardising design and production line methods of building, is a winch designed for a direct load of 30 cwts., and which provides a mean rope speed of 50 feet per minute—the cost of this winch is only £286.

This is a remarkably low price for a winch built to such a specification, and which incorporates so many features common to purpose-built winches of much greater cost.

Price list and specifications can be obtained on request. If you wish to discuss the performance of these winches, we should be glad to arrange for one of our engineers to call upon you.

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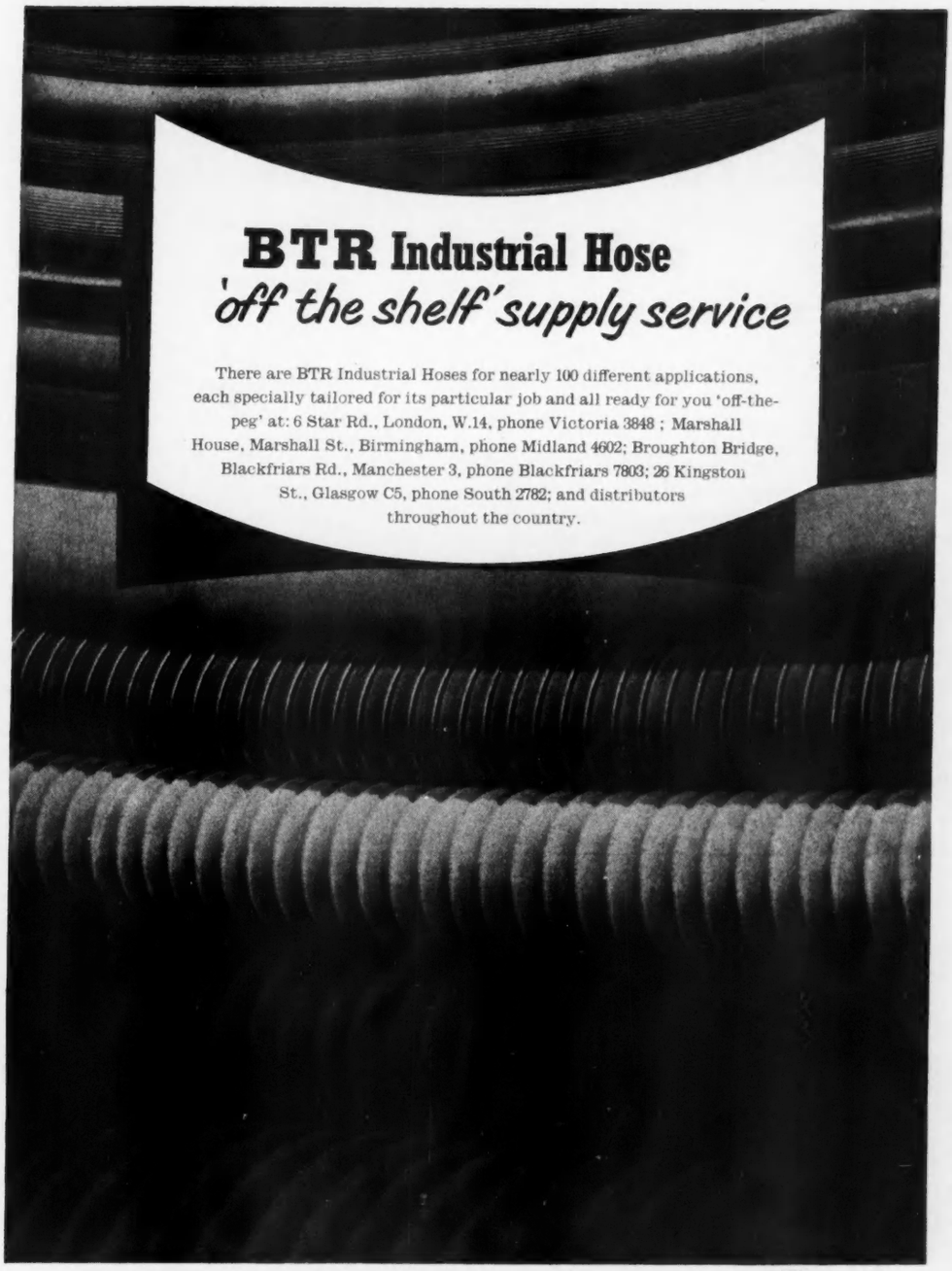

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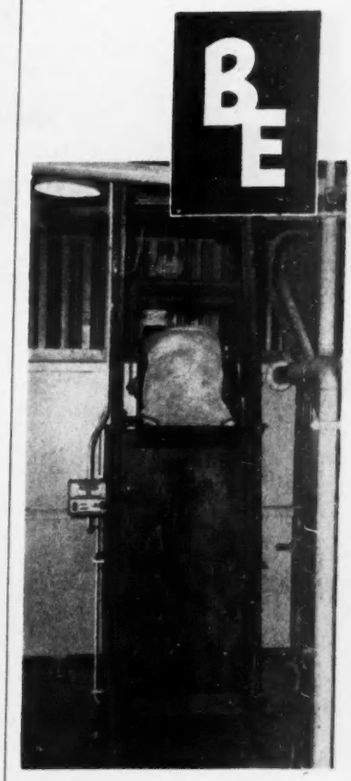

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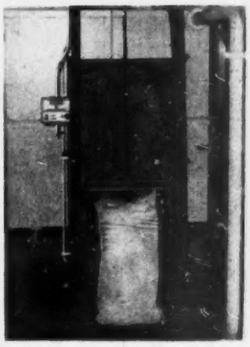

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Hollerith *plus*

On 30th January, The British Tabulating Machine Company Limited and Powers-Samas Accounting Machines Limited merged under the name of International Computers and Tabulators Limited.
This Company (I·C·T for short) is now Britain's largest manufacturer and distributor of data-processing machinery.
Its operations will be world-wide.

International Computers and Tabulators Limited

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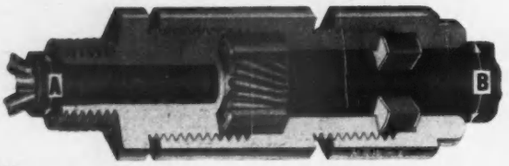
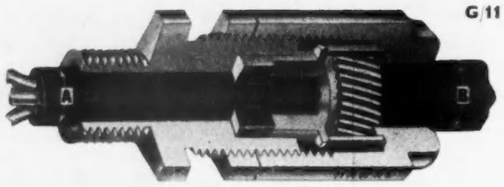


8/G3



G/11

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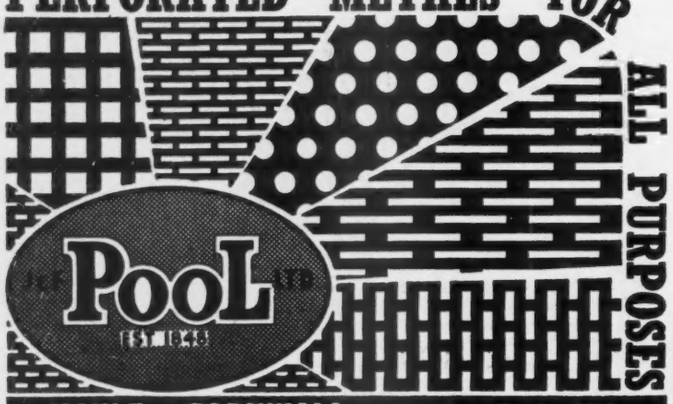

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Installed at the New Ford Motor Company Limited factory at Dagenham - Essex.

These photographs were kindly supplied by The Ford Motor Company Limited, to whom our acknowledgments and thanks are due for permission to publish.

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Powers-Samas *plus*

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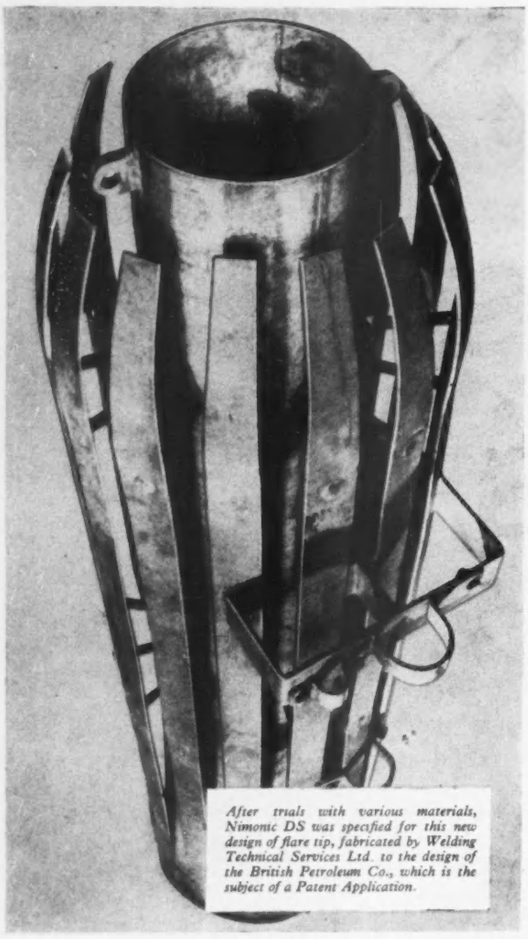
Its operations will be world-wide.

International Computers and Tabulators Limited



After trials with various materials, Nimonic DS was specified for this new design of flare tip, fabricated by Welding Technical Services Ltd. to the design of the British Petroleum Co., which is the subject of a Patent Application.

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The flare stack is one of the items of plant that the oil refinery engineer would like to fit and forget. Unfortunately, the severe conditions at the tip where waste gases are burned present considerable difficulties which put a limit on life. The temperature of the flare tip varies with the volume of gases exhausted, their calorific value and the temperature and velocity of the prevailing wind. These conditions are aggravated by the tendency of the flame to sweep downwards around the outer lee side of the tip. From the fact that even from the ground it can be seen to be glowing red, it is believed that at times the temperature may reach 800° C. As a result of trials with various materials at the B.P. Group's Llandarcy refinery, Nimonic DS was selected for a new design of flare tip. This nickel-chromium alloy has good resistance to both oxidizing and reducing atmospheres and retains much of its strength at temperatures up to 960° C.

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On 30th January, International Computers and Tabulators Limited (I·C·T for short) became Britain's largest manufacturer and distributor of data-processing machinery.

In this Company, Hollerith has been strengthened by its association with Powers-Samas—and Powers-Samas similarly strengthened by its association with Hollerith. These two Companies established the punched card industry in the United Kingdom and have remained in the forefront of world development in the data-processing field.

What advantages can I·C·T fairly claim? Among others:

The ability to make available a wider range of punched card and computing equipment.

A pooling of the wide variety of experience—50 years for Hollerith, 43 years for Powers-Samas—in mechanising statistical and accounting procedures and in contributing to scientific management at home and overseas.

The more effective deployment of research and development resources.

On the formation of I·C·T, The British Tabulating Machine Company Limited and Powers-Samas Accounting Machines Limited pay tribute to the very large number of users of their equipment in Government, Local Authority, Industry and Commerce, at home and overseas, with whose support the *Goodwill* of both Companies has been firmly established. I·C·T is proud to take over this *Goodwill*, and assures both present and prospective users that it will be as strenuously guarded as in the past and strengthened in the future.

I·C·T

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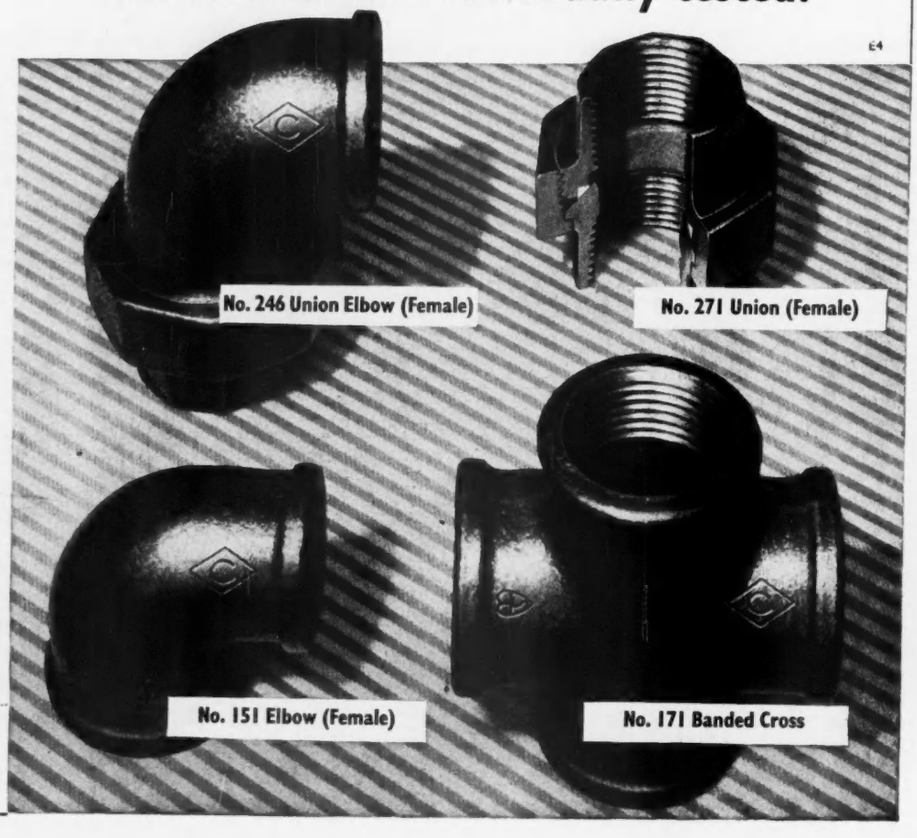
There are four types: Iron to Iron; Bronze to Iron (Railroad) and Bronze to Bronze (Navy)—all with spherical seats; and Flat-face gasket type. All have British Standard taper threads. Sizes ⅛" to 4". *Write for full details.*



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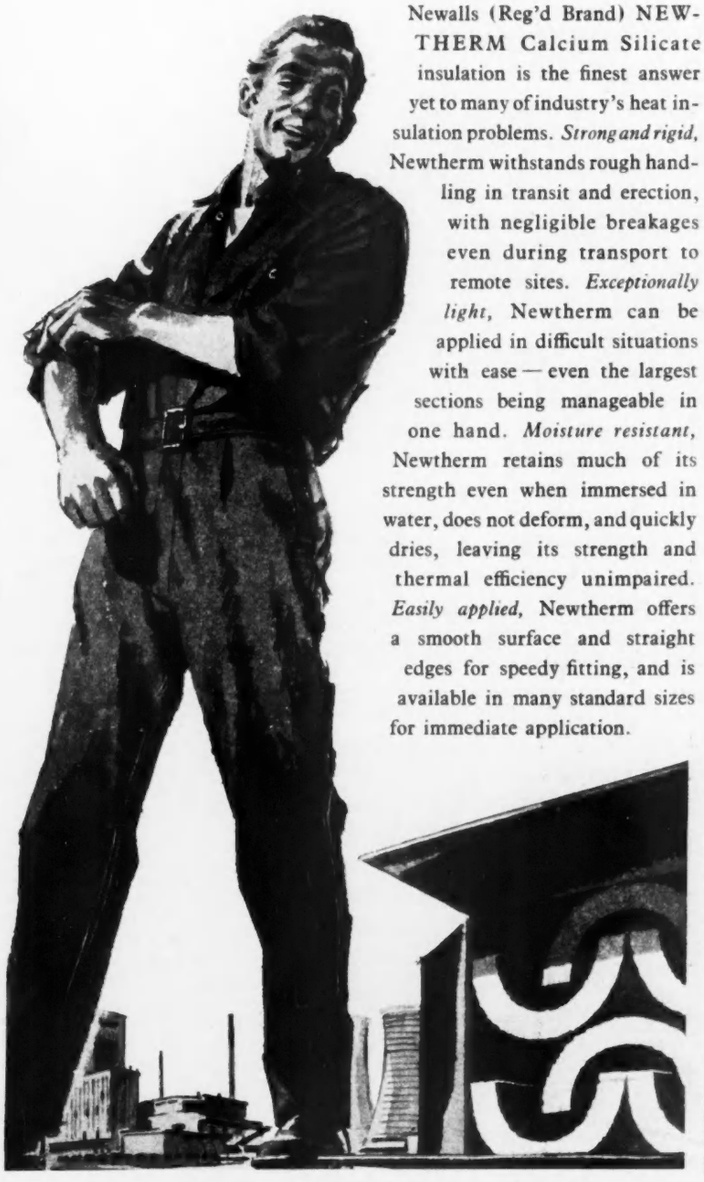

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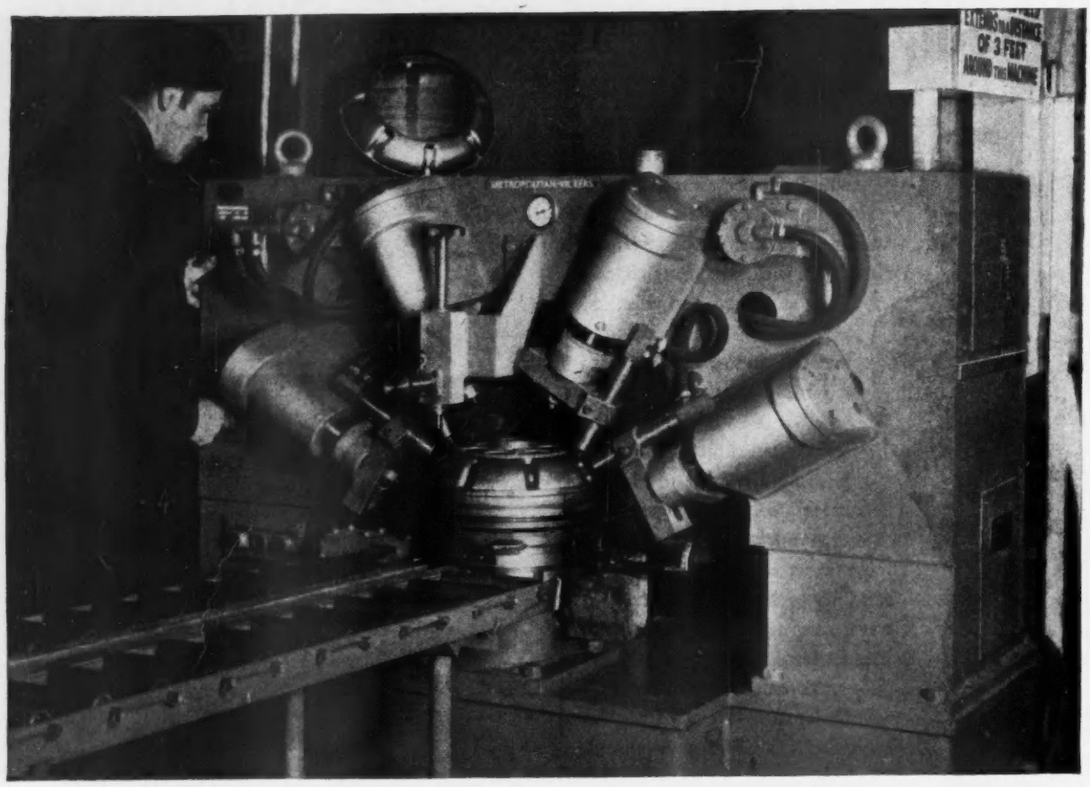
Metrovick Welding Equipment for Modern Engineering



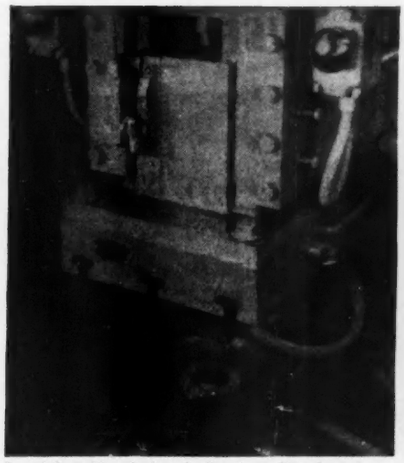
Borg-Warner automatic transmission used on British and Continental cars is now produced entirely in this country. The fabrication of the hydraulic torque converter is an achievement which depended largely on solving a number of welding problems. Distortion had to be avoided because of the close dimensional tolerances required in many components and only a small departure from true balance is permissible with the high rotary speeds employed in the converters. In addition, the economics of present-day production necessitated fast, automatic welding techniques. All of these exacting and important welding requirements have been met by the use of several different types of Metrovick automatic submerged arc and resistance welding equipments, including a number of machines specially designed for the job.

METROPOLITAN-VICKERS
ELECTRICAL CO LTD TRAFFORD PARK MANCHESTER, 17

An A.E.I. Company

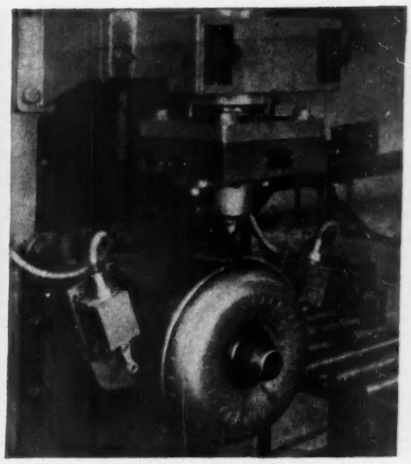
LEADING WELDING PROGRESS

L/W803



1. After the hub of the impeller has been pressed into its shell, the hub plate is welded inside the shell using a Metrovick 600 kVA projection welder.

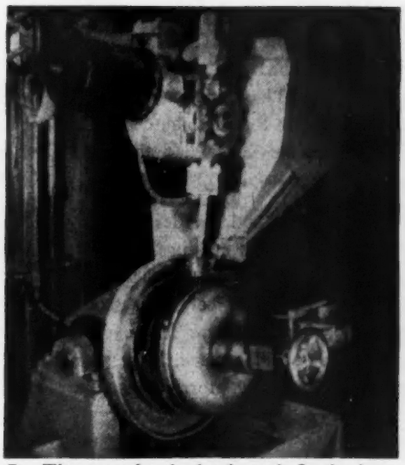
2. For welding the hub to the impeller shell a Metrovick submerged arc unit is used. An essential feature of this machine is the electronic control of the arc.



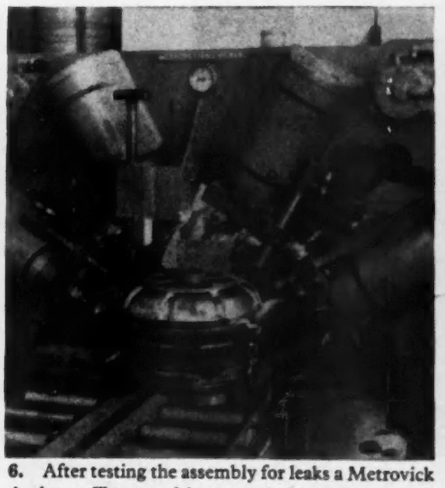
3. After vanes have been inserted, a filler adapter drain plug is welded into the impeller shell. A counterbalance weight is welded on the diametrically opposite side. This is carried out on a Metrovick 150 kVA air-operated projection welder, automatically setting the weld time for each operation.

Fabricating the BORG-WARNER HYDRAULIC TORQUE CONVERTER

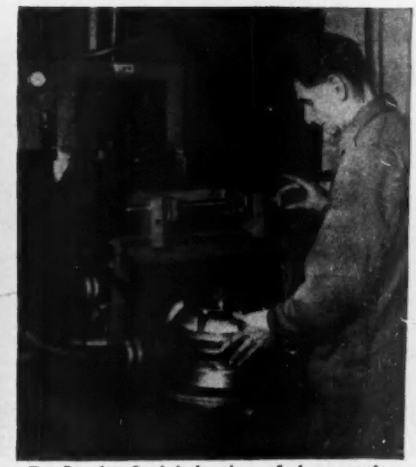
4. The turbine assembly must be balanced to within 0.1 oz.-in. Balance is corrected by spot welding strip metal on to the vanes using a Metrovick 50 kVA portable machine.



5. The completed clutch and flywheel assembly and the converter assembly are fitted together and then welded with a Metrovick submerged arc machine. This was specially designed for circumferential welds on Borg-Warner converter casings.



6. After testing the assembly for leaks a Metrovick Archway Type multi-spot unit is used to attach the blower. Sixteen spot welds are made with four air-operated heads. Control is by thyratron timer and ignitron contactor.

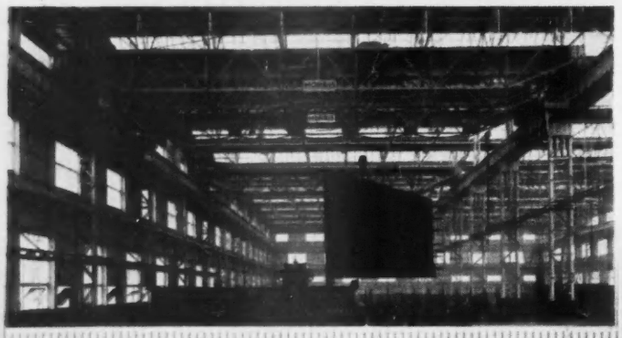


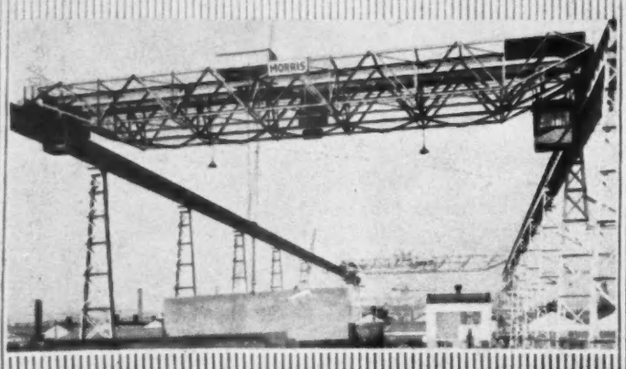
7. In the final balancing of the complete assembly this Metrovick 75 kVA portable spot welder is used for welding weights to the outer casing. The air-operated welding gun is mounted on a pivoting arm, balanced for ease of manipulation.

HARLAND and WOLFF LTD. USE

Our photographs by courtesy of Harland & Wolff Ltd., show only seven of the many cranes installed at their various works.

MORRIS CRANES





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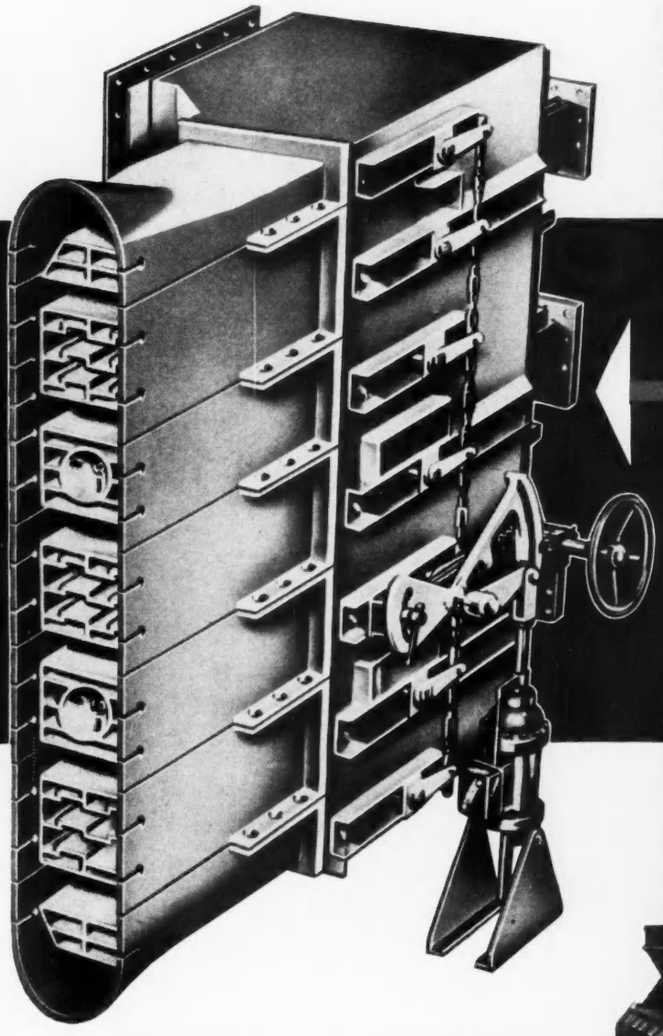
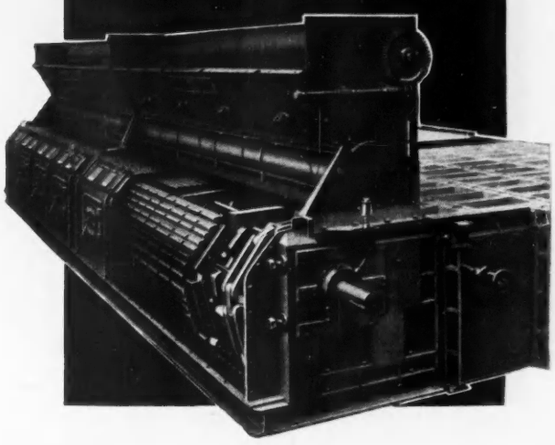


Burner
or
Stoker?



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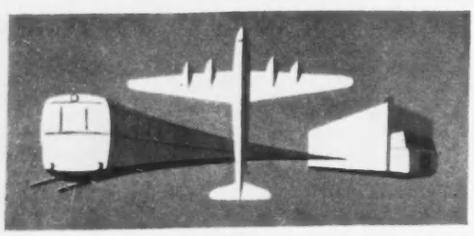

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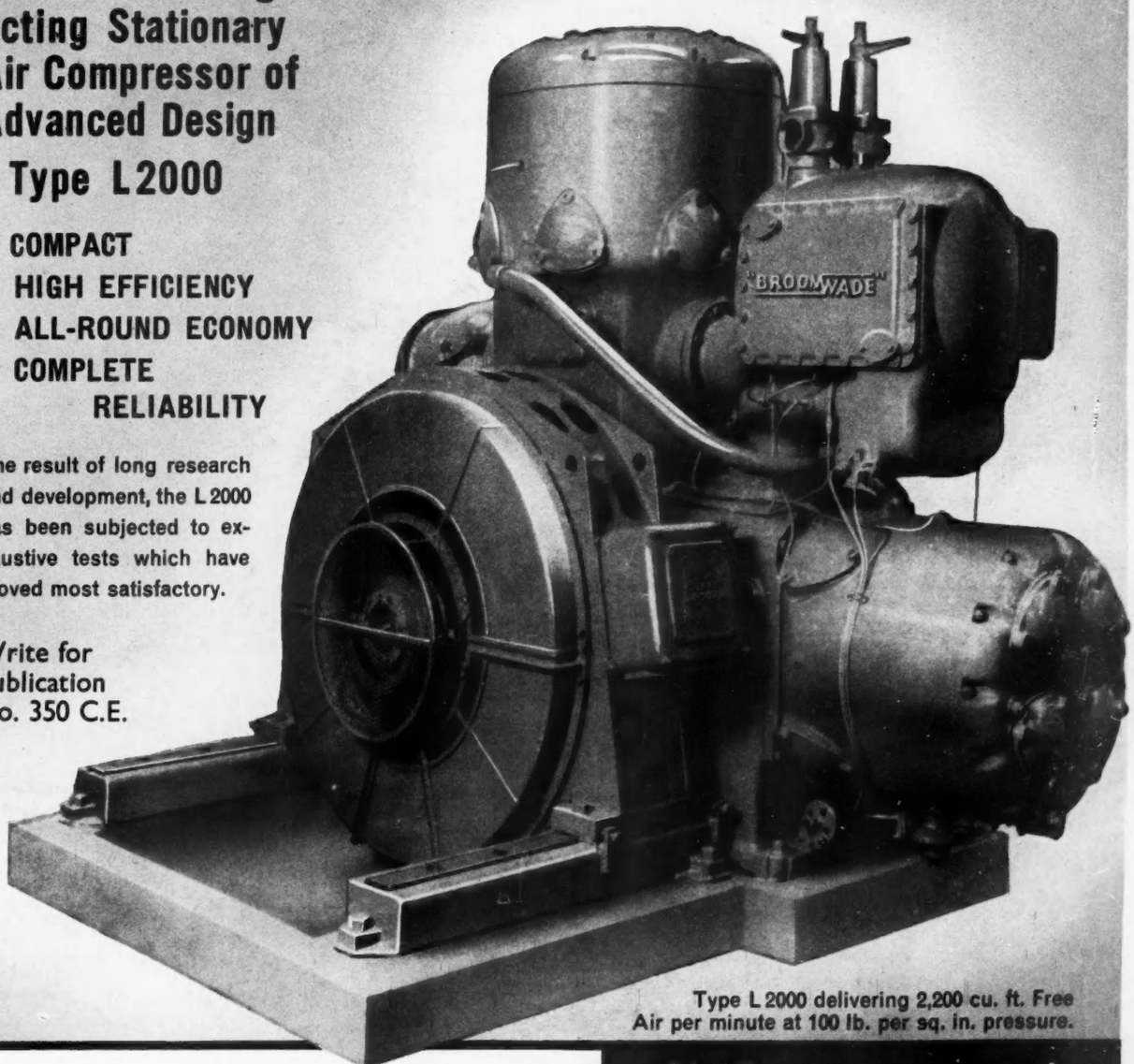

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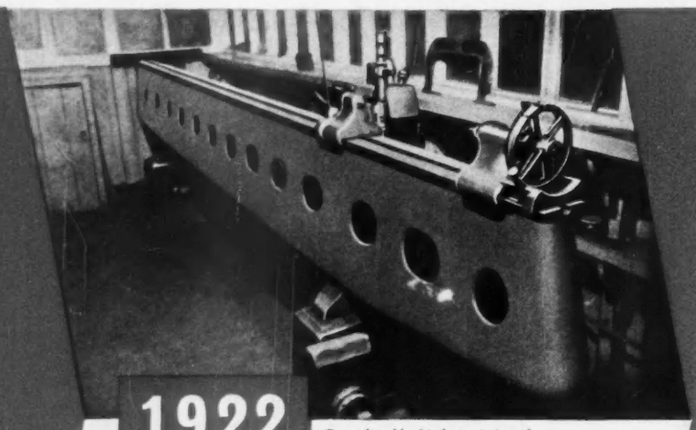

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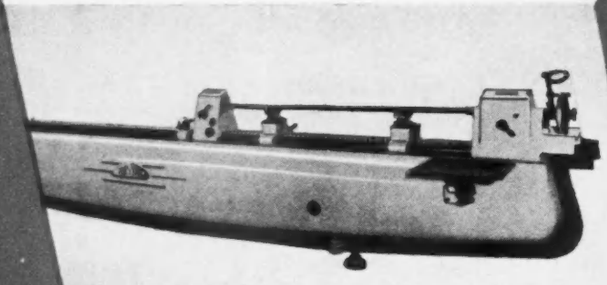

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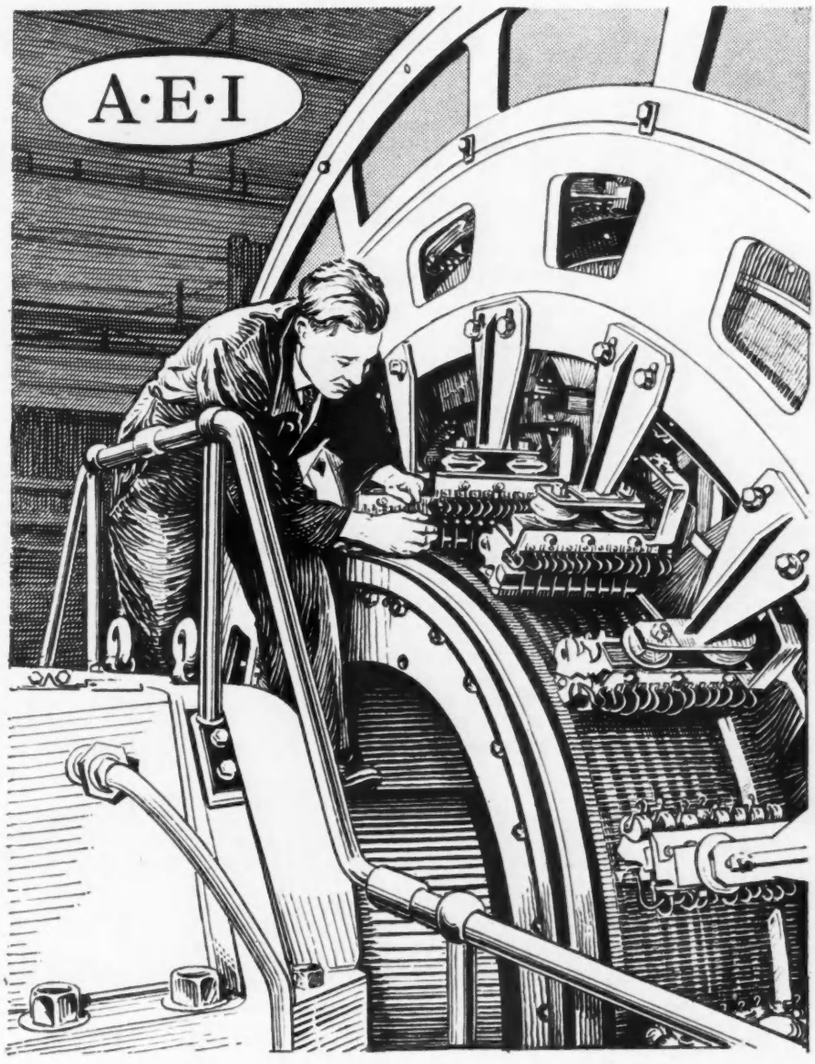

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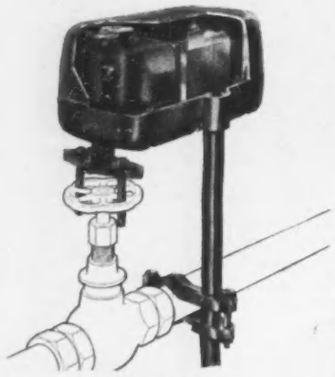

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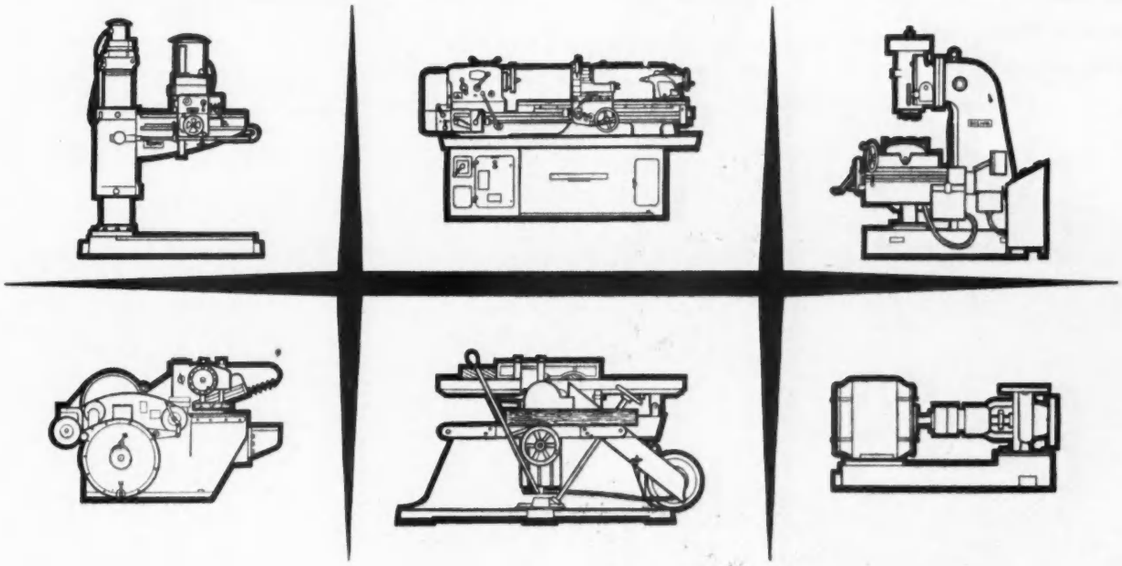

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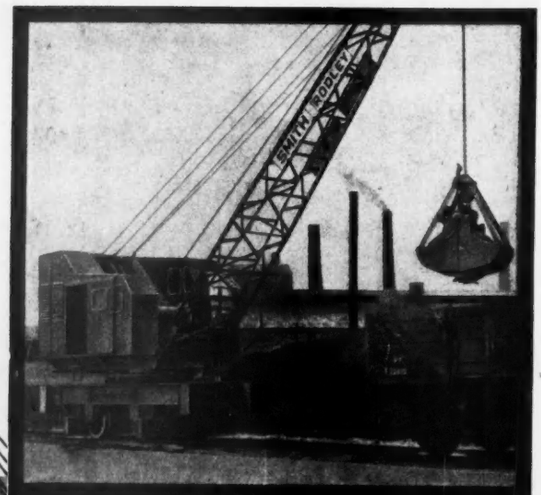
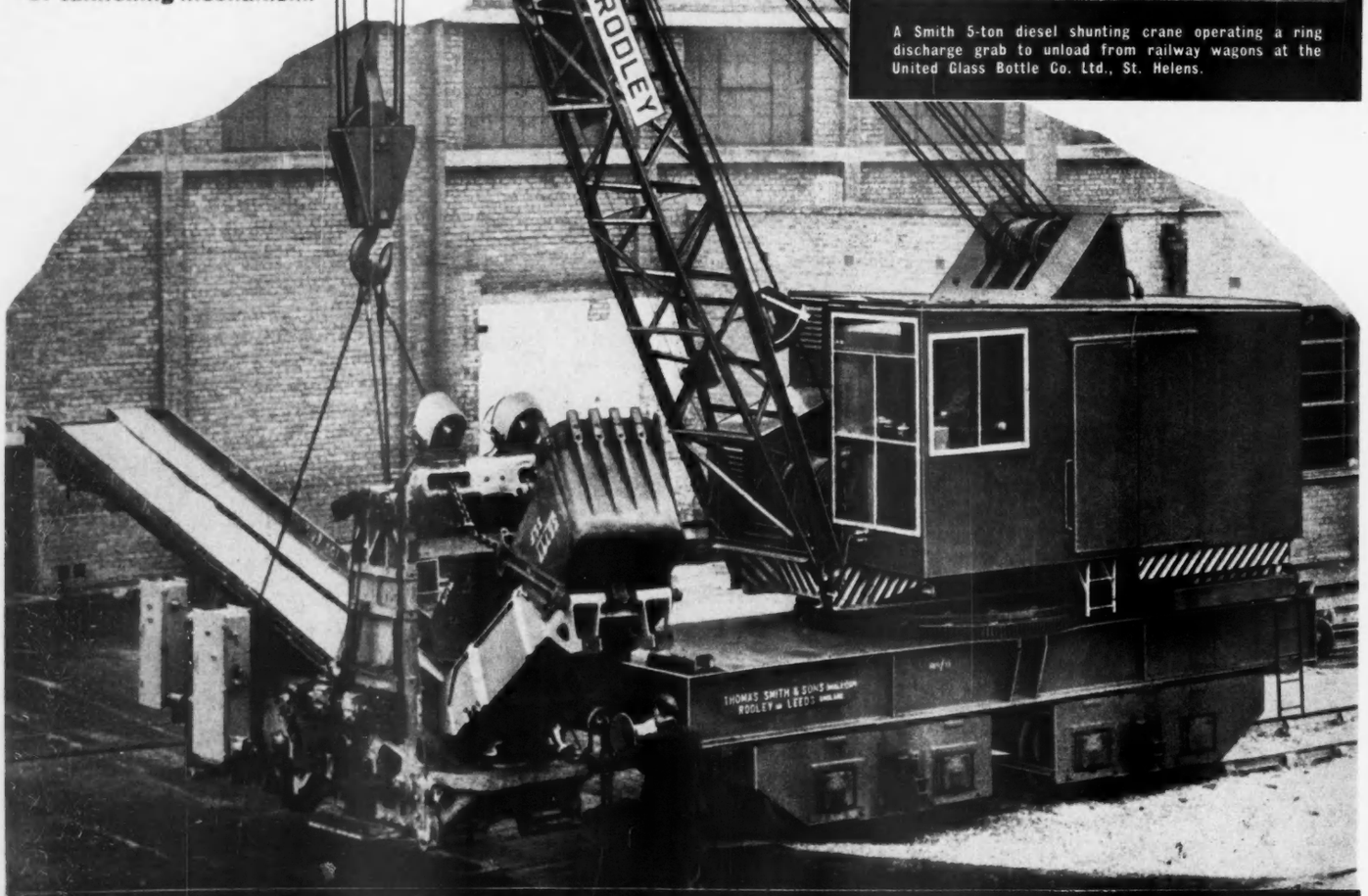
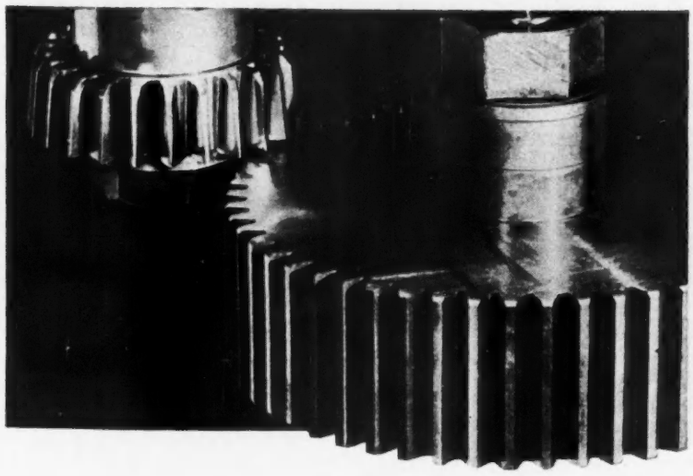


A Smith 5-ton diesel shunting crane operating a ring discharge grab to unload from railway wagons at the United Glass Bottle Co. Ltd., St. Helens.





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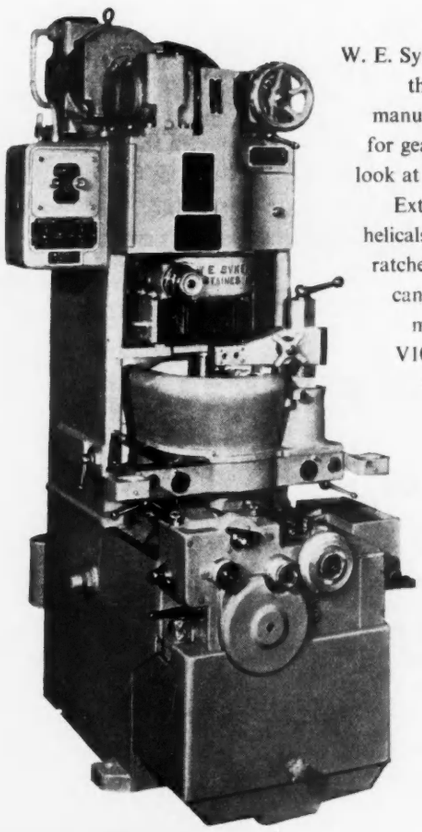

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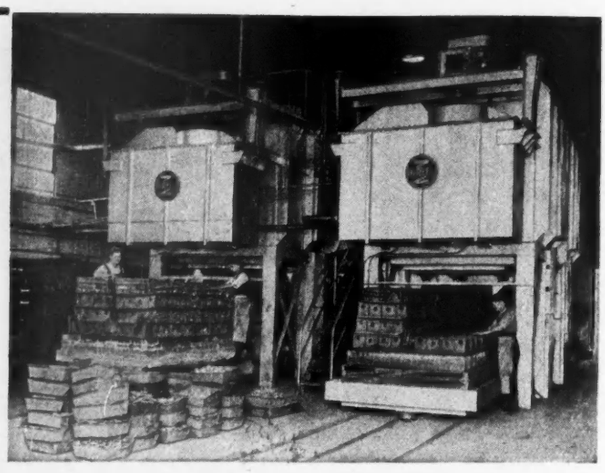

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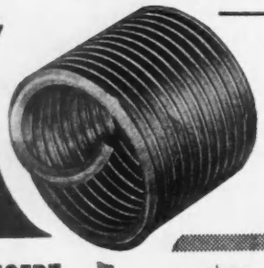

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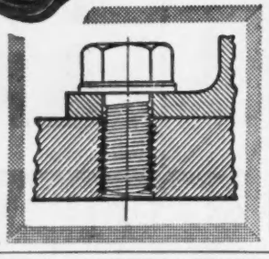

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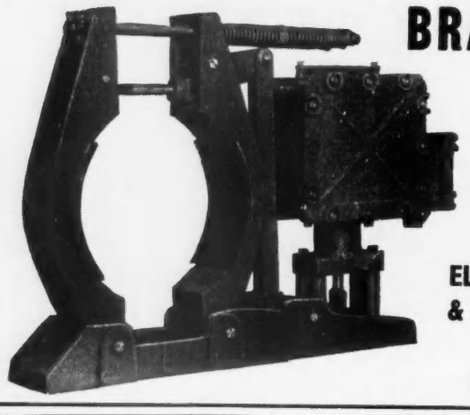

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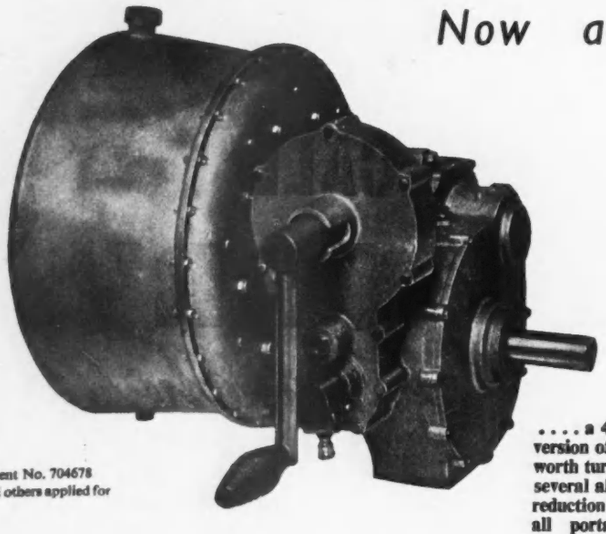

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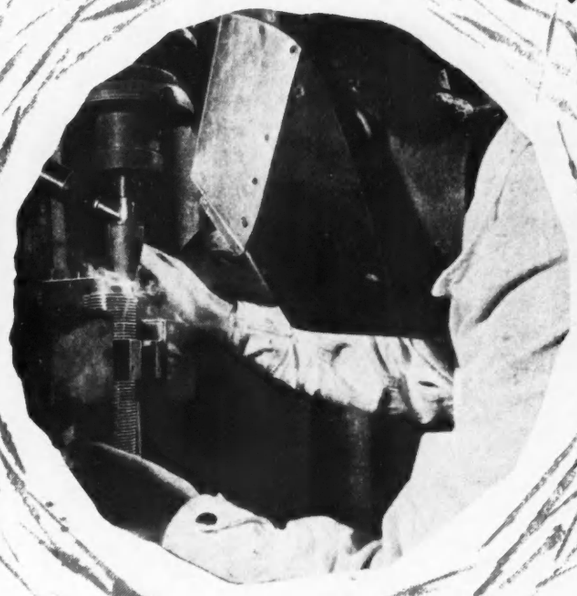

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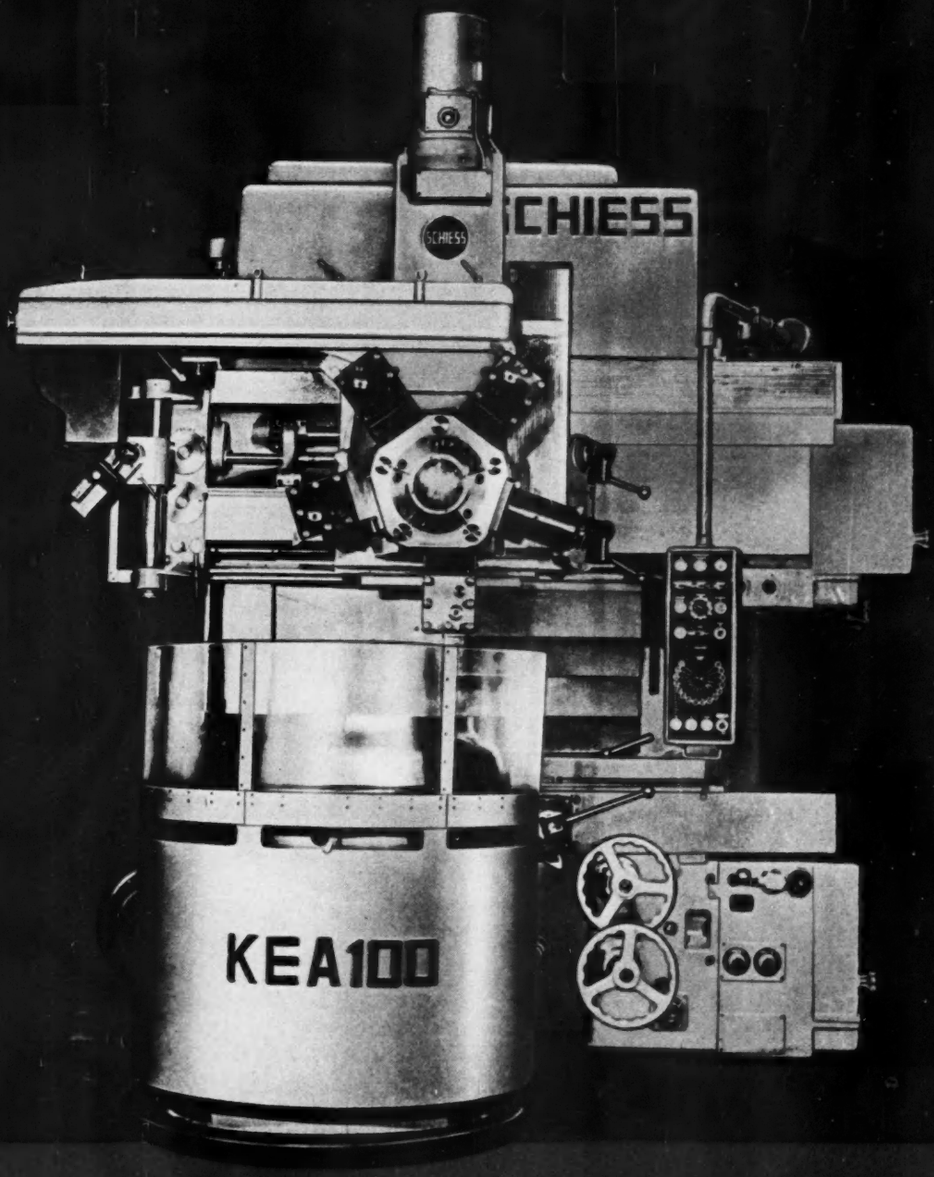

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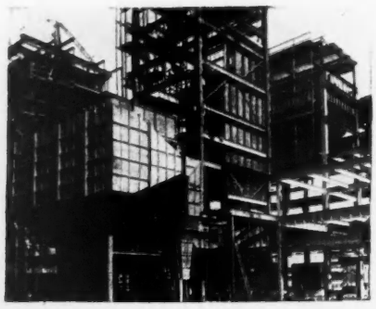
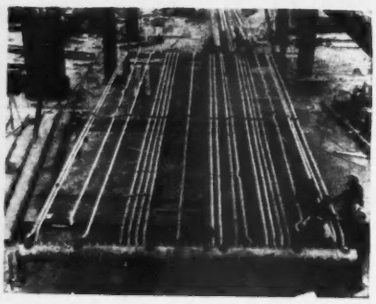
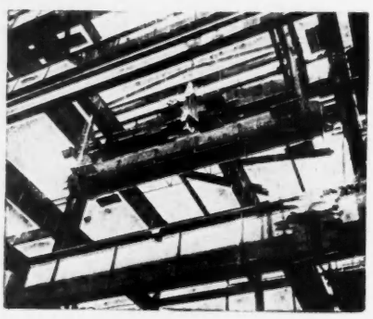


Little Barford 'B' Power Station. "Outdoor installation of 2 boilers".



Aberthaw Power Station. "Panel wall construction on site for one of 6 boilers".



Drakelow Power Station. "Drum lift for one of 3 boilers".

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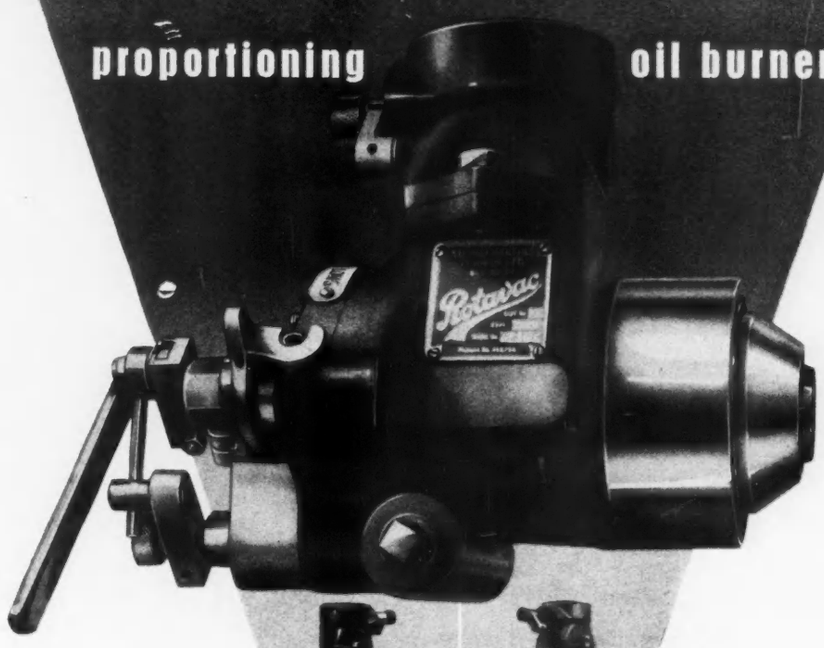

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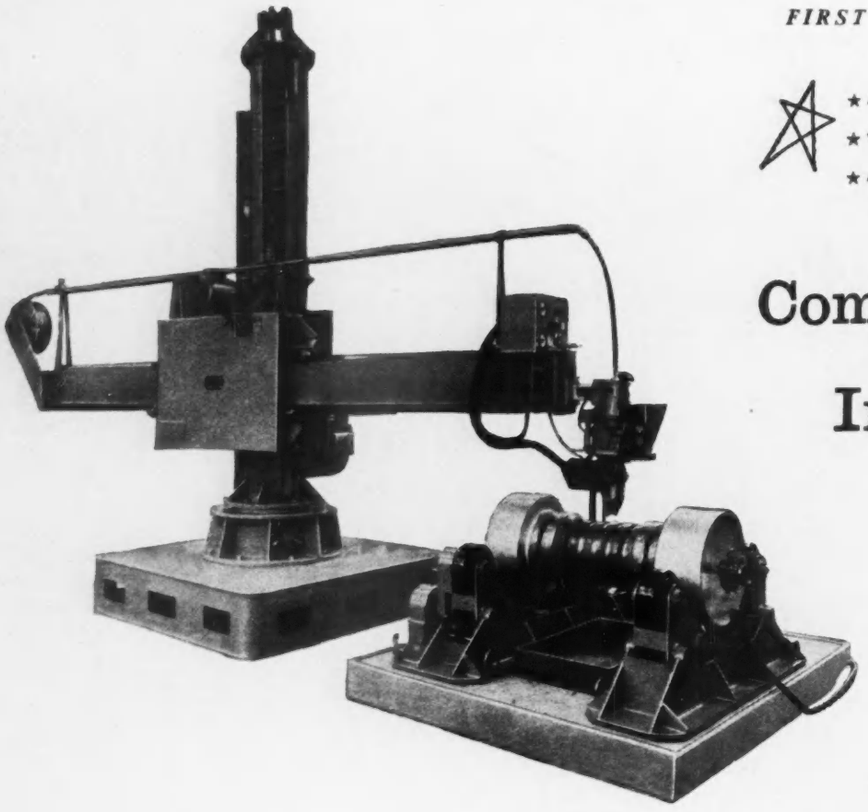

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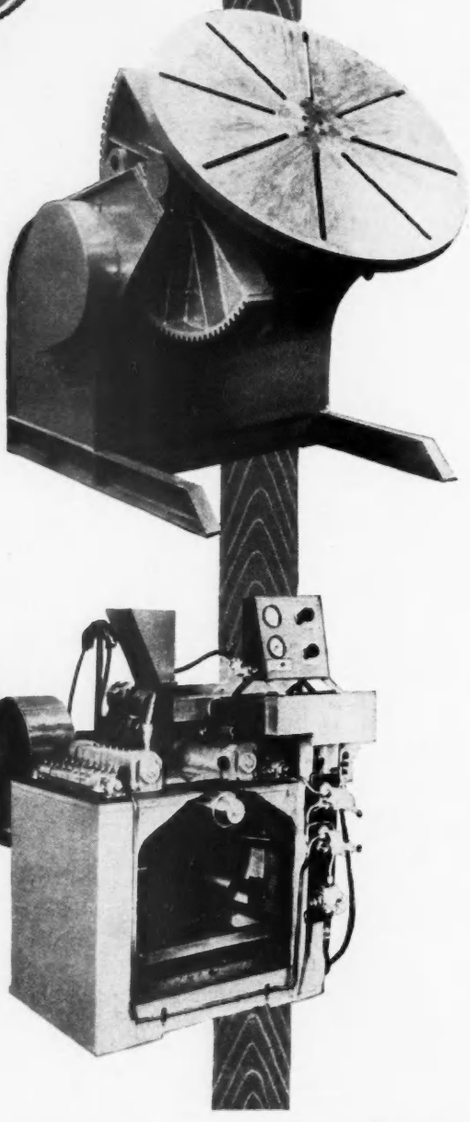

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On the right is the LINCOLN 150 L.V.P. Variable Speed Positioner with a load capacity of 7½ tons, which is particularly suitable for heavy plate fabrication using either automatic or hand welding techniques. Shown below right is a LINCOLN Seam Welding machine incorporating a LINCOLNWELD M.L.3. Remote Control Automatic Submerged Arc Welding Unit.

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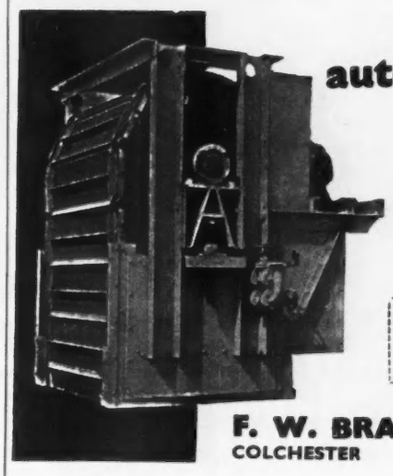

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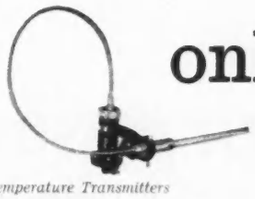

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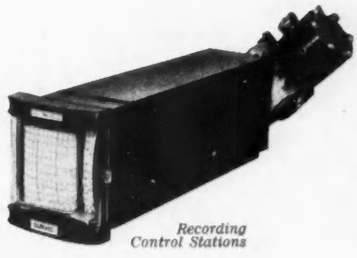

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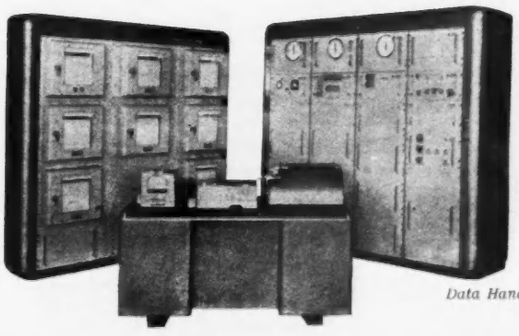

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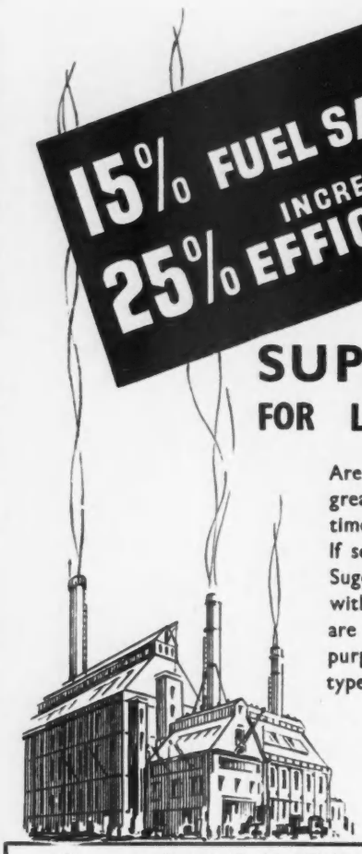

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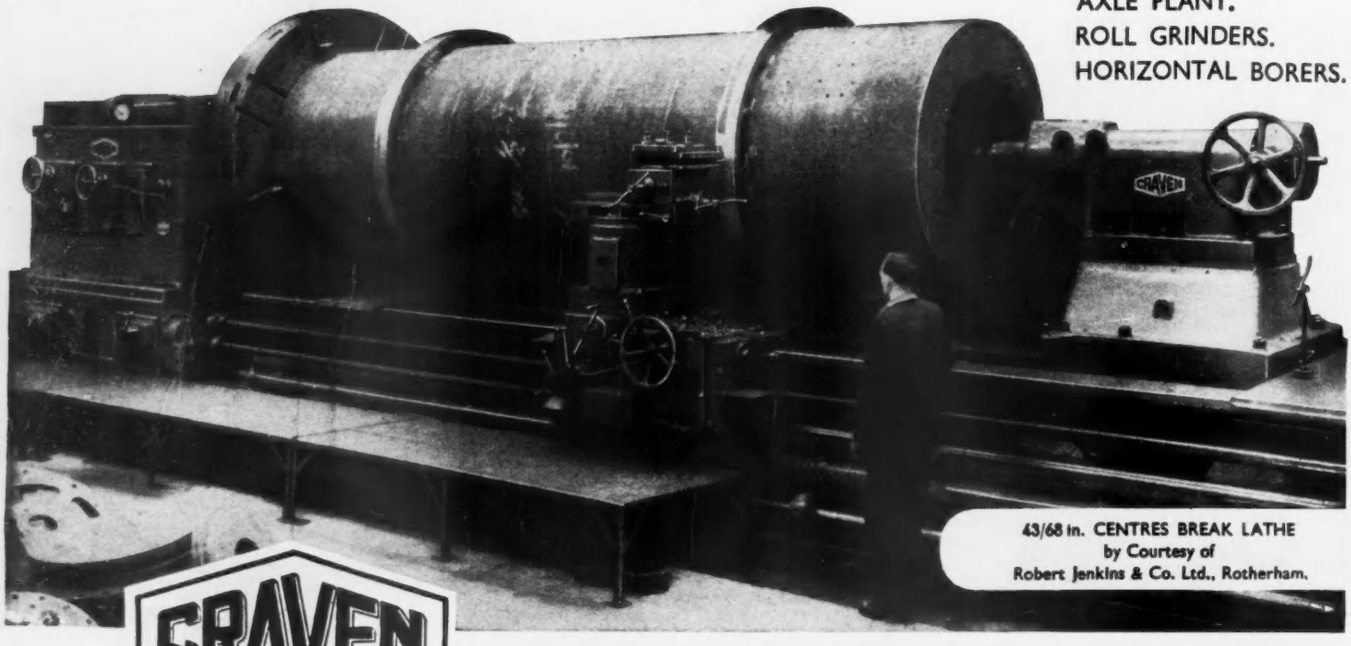

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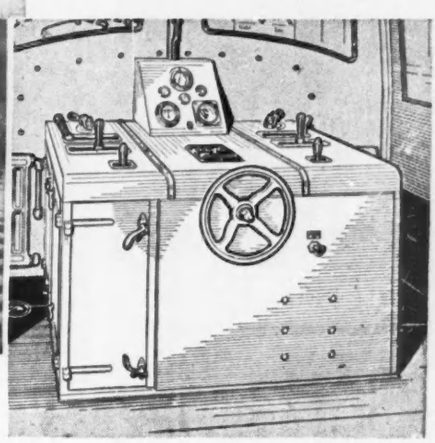

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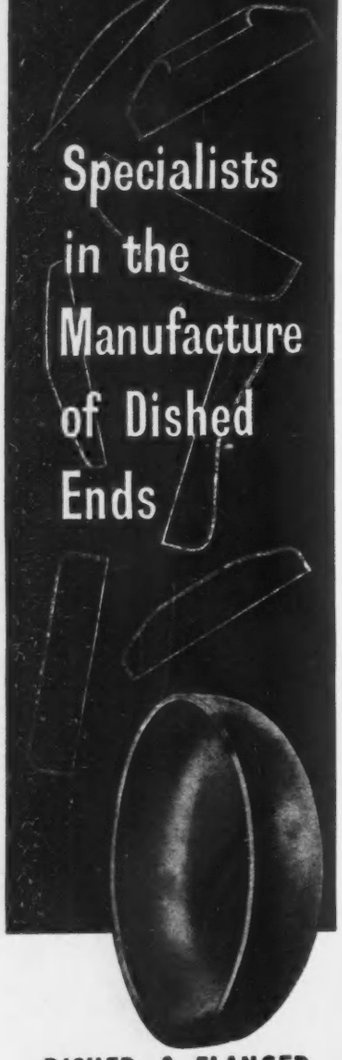

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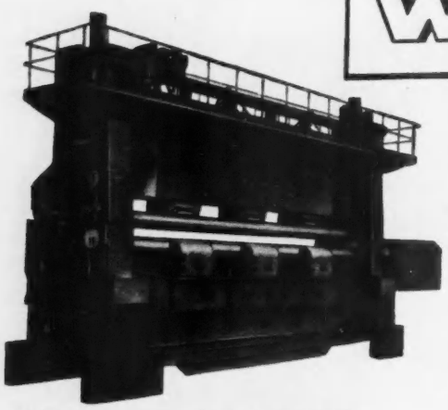

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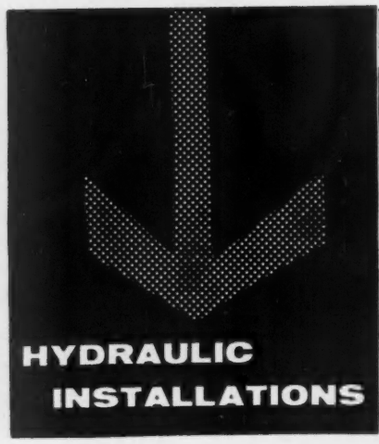

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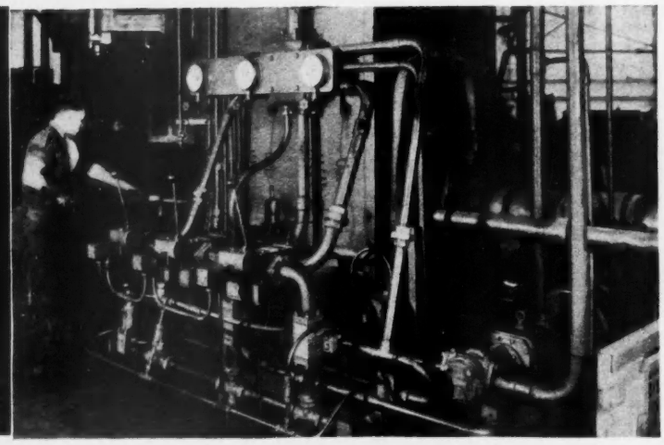

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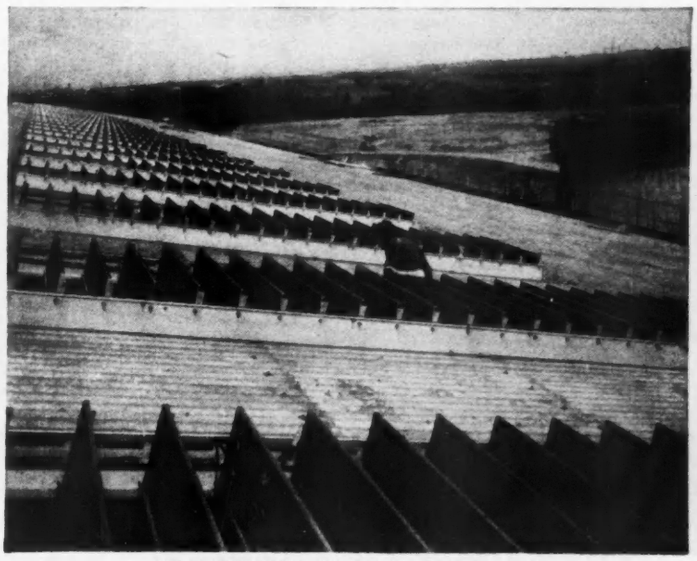

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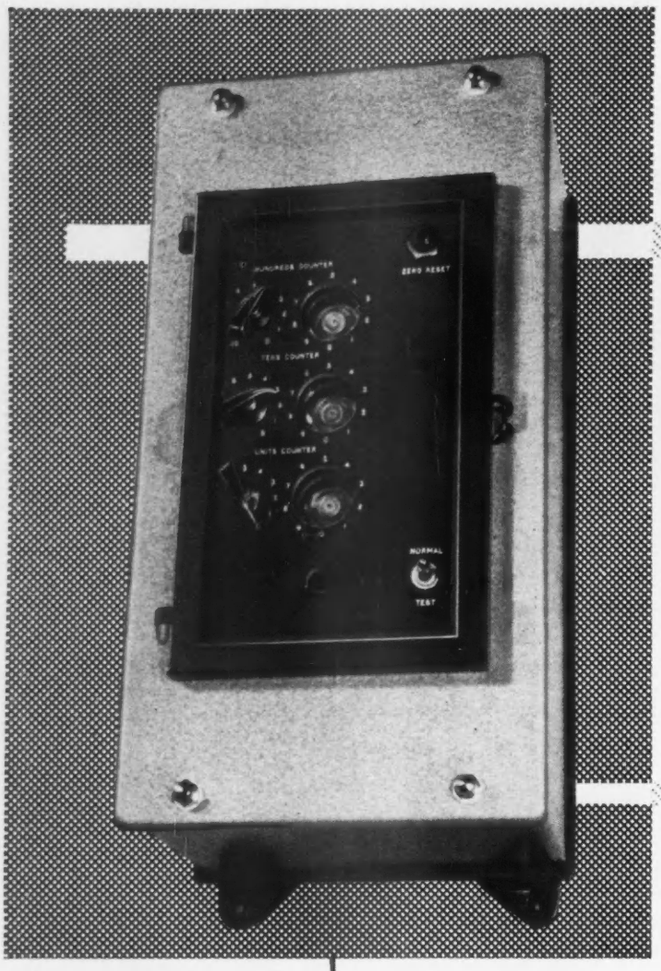

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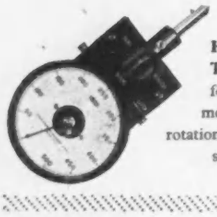

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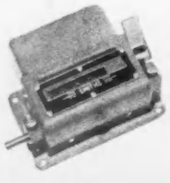

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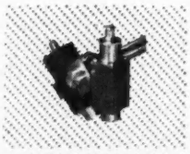

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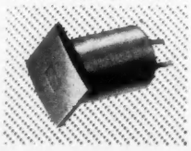

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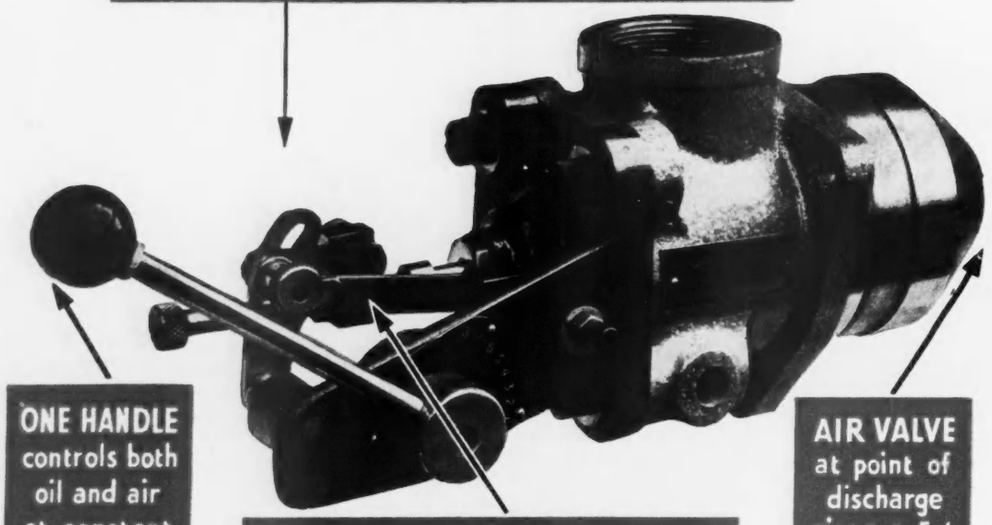

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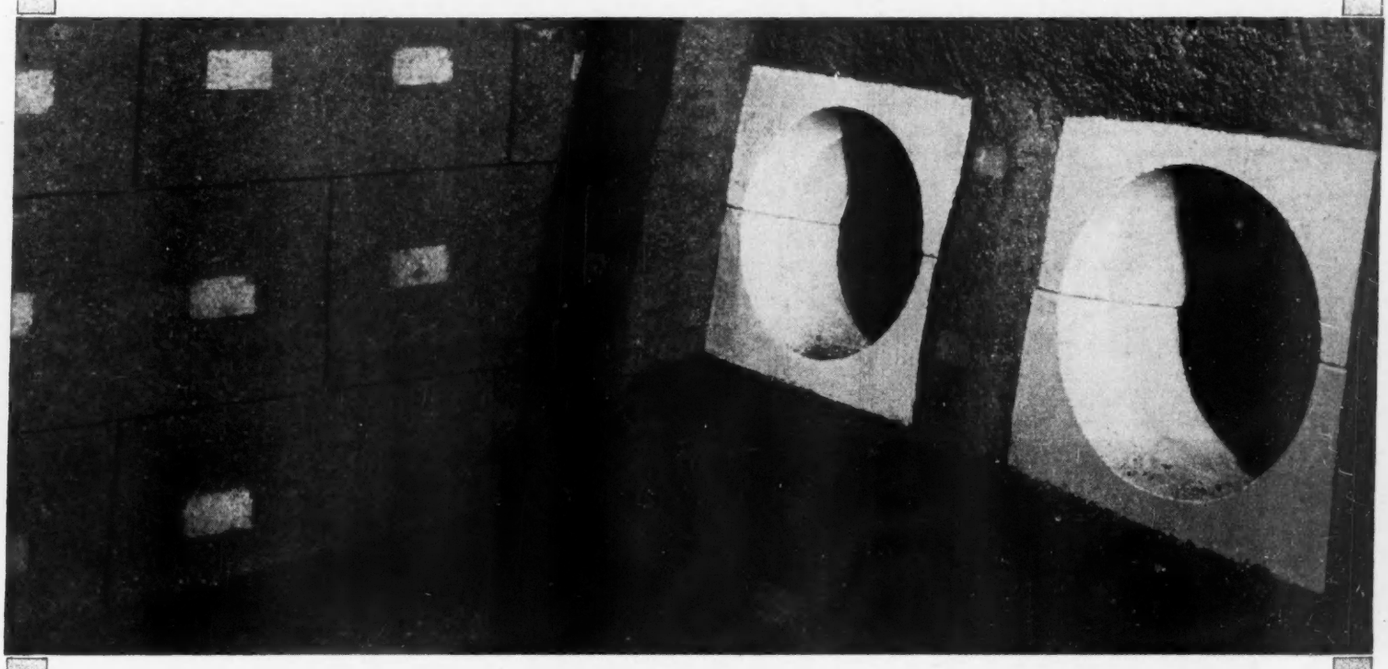

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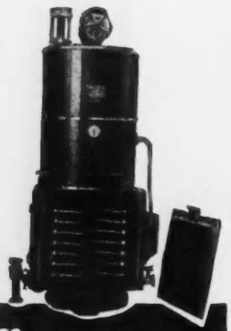

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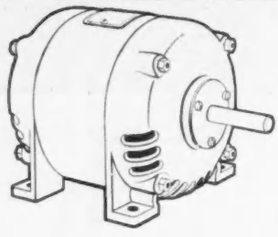

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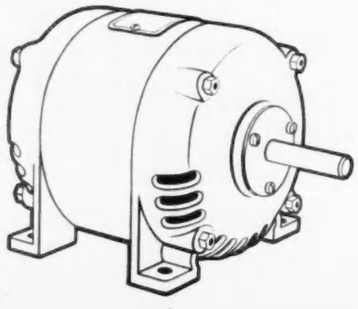

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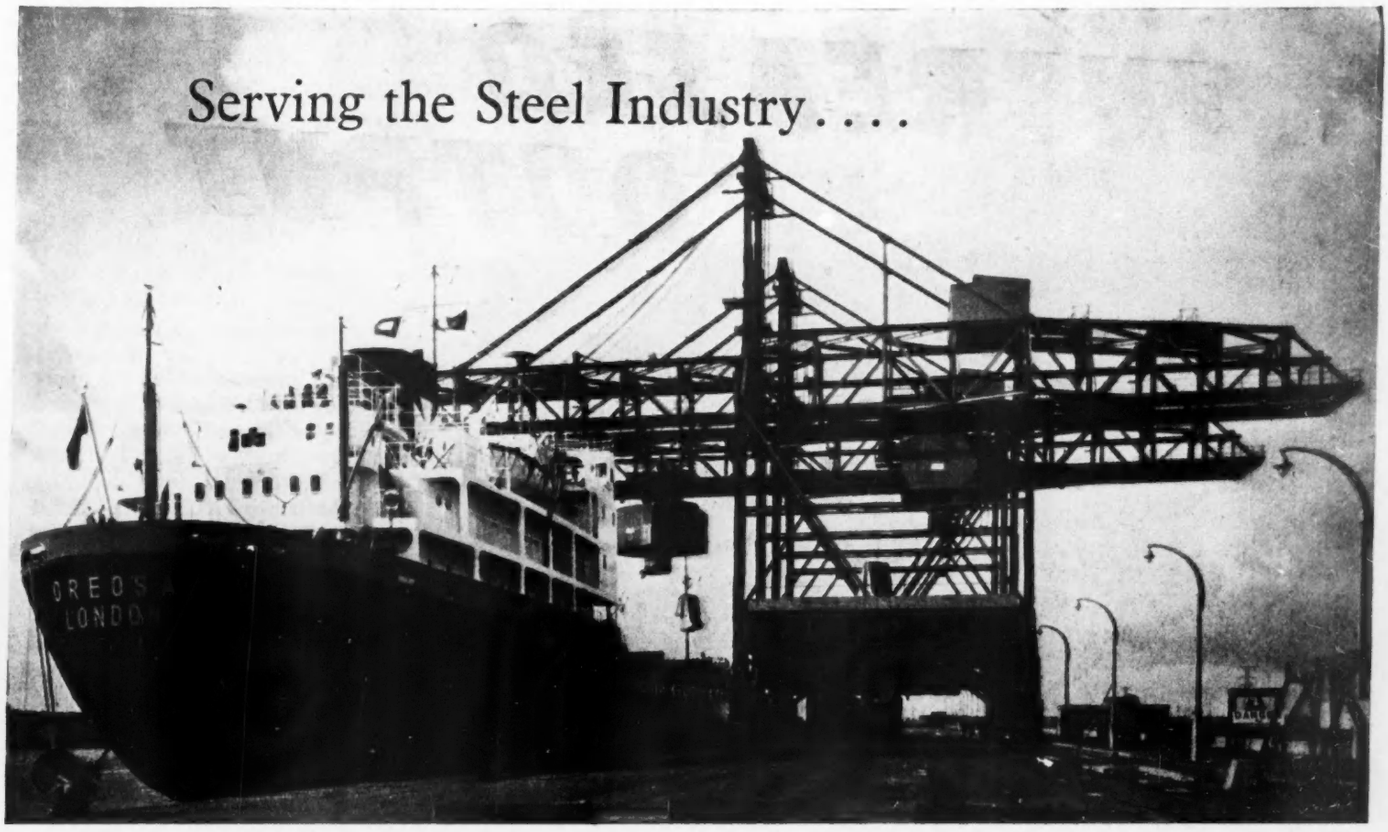

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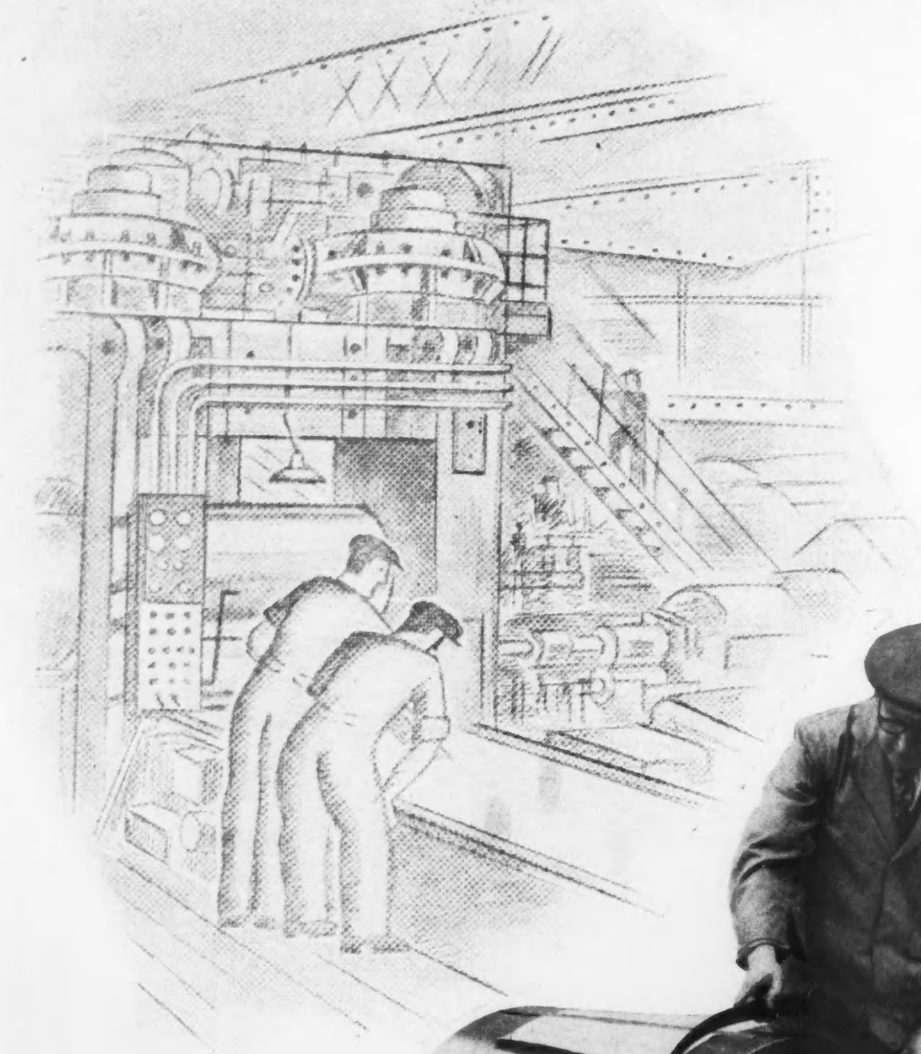

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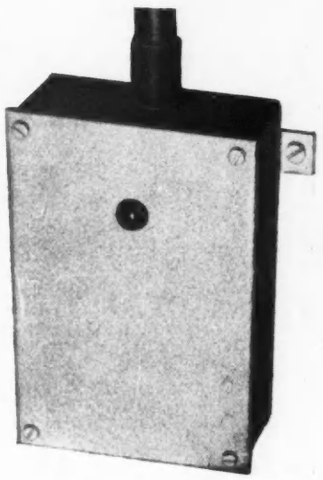

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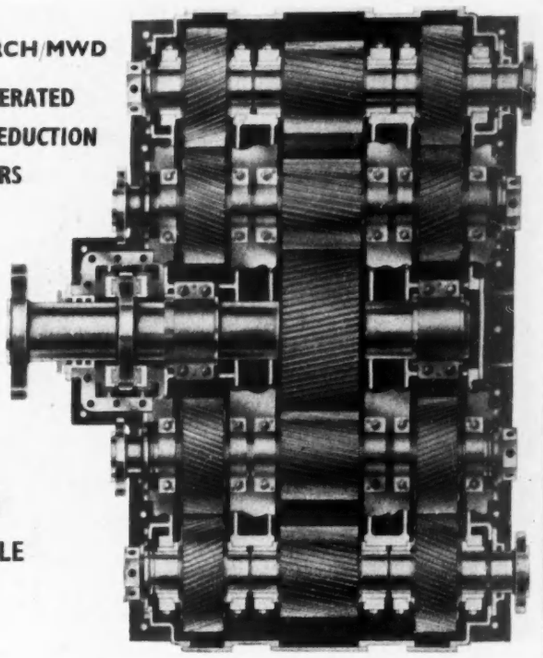

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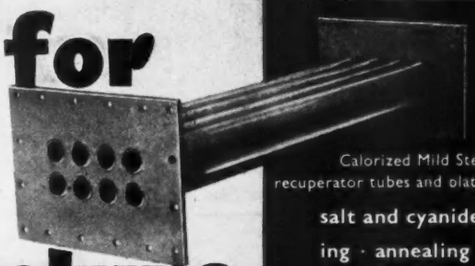

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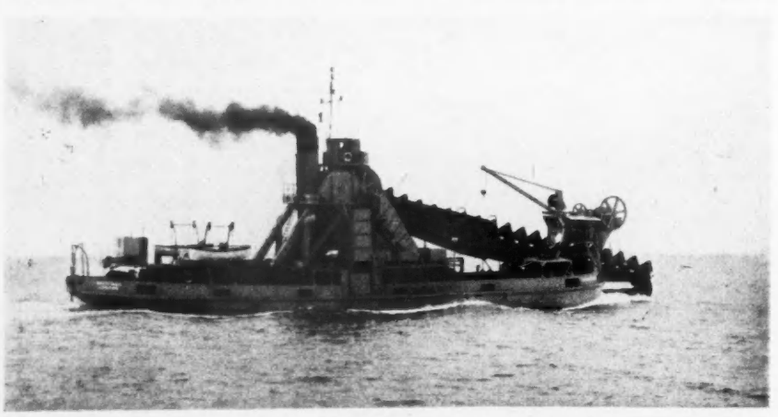

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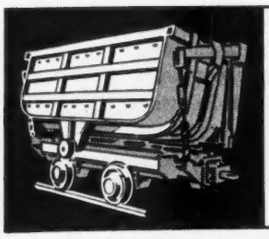

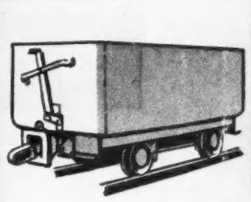

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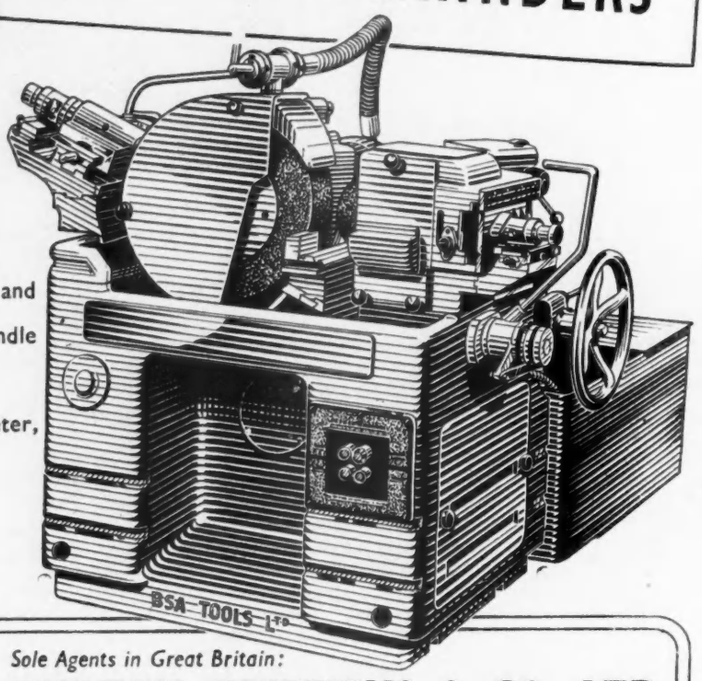

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THE ENGINEER

No. 5377 FEBRUARY 13, 1959 VOL. 207

SCIENCE MUSEUM CHANGES

Rather more than eighteen months ago when the Science Museum in South Kensington celebrated its Centenary we ventured to comment that it was failing to live up to one of its declared objects, that of presenting scientific and technical knowledge to a visitor in such a way that he would be attracted and interested and have his imagination stirred. For, we suggested, to the layman much that is on view appears esoteric and cannot be comprehended without a much greater knowledge than he is likely to possess of the elements of the science or technology involved. Furthermore the museum fails, we suggested, to put across to the public how much the advancement of technology has done to affect the lives of ordinary people. We complained that because of lack of space a visitor to the museum often felt battered mentally by the crowd of objects meriting his attention. We might have added that the method so freely adopted of placing a mass of exhibits in show cases is not well adapted to attractive presentation.

Last week, as we announce on another page, there was opened at the museum a re-arranged gallery devoted to the iron and steel industry. In declaring the gallery open Lord Mills remarked that there was no better way of starting a youngster upon a technological career than by providing for him arresting and vivid answers to his questions "how" and "why." He believed that the new gallery would serve a very great purpose. Certainly it seemed to us when we visited the gallery that there is a very great improvement in the presentation of the iron and steel industry to the public. Indeed the opening of this gallery severely shows up the urgent need to re-arrange and re-organise not merely other galleries but the whole of the exhibits in the museum ! Standing in the newly arranged gallery and using it as an example of what might be, we looked down upon the main floor and across to other galleries and had a vision of the museum re-arranged upon a much more attractive plan—a plan which would make it easy for the uninitiated to comprehend the historic development of any technology and to realise how vast has been the influence of technology upon the development of our twentieth century civilisation. We saw the museum not solely as a place, as it is at present, where historic relics are collected, so that the historically minded can study in esoteric detail every tiny step in the development of technological devices, but as a place, primarily, aiming to present the grand broad sweep of technological advancement for the comprehension of people whose ways of life lie in other fields. For far too long in this country it has been pretended that technology is not a cultural subject, that a man can be a cultured and civilised individual despite a lack of any appreciation of applied science. We saw a re-arranged museum boldly proclaiming that to attain a full appreciation of life men must visit its floors as freely and often as they visit those of the Victoria and Albert Museum of applied art across the road.

We cannot say that the newly arranged gallery wholly accorded with our vision. It seems to us, indeed, that those who arranged it were never quite certain whether its appeal should be to the layman or to the student who has already chosen that his way shall lie in iron or steel making or in engineering or some allied technology ; and the cultural note, that is the one which stresses the influence of iron and steel developments on the way we all live our lives, is almost wholly absent. But we do not wish to carp. The improvement upon what went before is immense. Would that similar improvement could be made elsewhere ! But, rather shockingly, we doubt whether it is within the power of the museum authorities, alone, to initiate very much change. The cost of re-organising the gallery, obtaining new exhibits and so forth is stated to have been £60,000. It may well have been more in reality as certain models and certain exhibits were presented by individual firms. That cost of £60,000 was met not by the museum but by the industry. Precisely how the museum is situated financially is more than can be discussed here. But it is strongly our impression that it could afford nothing approaching such a sum for the re-arrangement of a single small gallery without appealing for and obtaining a special grant from the Ministry of Education. Thus if our vision is to come true the museum must have both more space—for its floors are much too tightly packed with exhibits at present—and more money. Space is on the way. A new block is being built upon whose completion floor space will be substantially doubled though it will still remain far below the 500,000 square feet which the Bell Committee considered necessary as long ago as 1909. But dare we hope that when that space becomes available the Ministry of Education will be able to extract from the Treasury a sum sufficient to permit the whole presentation of science and technology by the museum to be modernised ? We wish we could feel really confident about the outcome. For we believe that a re-arranged Science Museum could play an important part in raising the social status of technologists in this country nearer the level they enjoy abroad and in attracting to the ranks of engineers a larger fraction of talented youngsters each year. It is still true we think that many youngsters are never properly and accurately informed of the attractions of a career in engineering or some other technology. A well arranged Science Museum could help to rectify that omission.

STABILITY OF LARGE TURBO-GENERATORS

In last week's issue we referred to an I.E.E. paper by Mason, Aylett and Birch, which discussed turbo-generator performance under exceptional operating conditions, with special reference to a series of tests carried out on a standard 60MW hydrogen-cooled set at Stella North power station. The significance of the work done by these authors is enhanced when the results they derived are studied in relation to kindred tests done at other British power stations, including Cliff Quay, Marchwood, Castle Donington and Poole. Perhaps the main

conclusion to be drawn from all these tests is that turbo-generators equipped with continuously-acting high-response automatic voltage regulators can be run safely and steadily under conditions of leading power factor, beyond what is regarded as the normal stability point. Therefore it should be easier than had been previously supposed to supply the leading-power-factor reactive kVAr required by the 275kV super-grid at times of low system load. Furthermore, it becomes possible to relax existing generator stability requirements, allowing the generator short-circuit ratio to be reduced. This relaxation will enable higher ratings to be applied to a rotor of given physical size. Since transport limitations govern the maximum physical size of turbo-generators in this country, the improvement discussed above implies that ratings above 275MW per shaft are practicable : an increase of 10 per cent has been suggested and further improvements may lie ahead.

It is likely that the past work, which has already been so fruitful, may stimulate further studies on similar lines. The discussion at the recent I.E.E. meeting indicated that one of the immediate tasks is to correlate all the tests that have already been carried out on different turbo-generators under somewhat different conditions. It should then be possible to make generalised deductions and to offer some guidance as to the most promising lines of advance for the future. For tests of the kind we are discussing are expensive and require a great deal of detailed organisation. Some of the work can, no doubt, be done with scale experiments, using analogue and digital computers, and these aids are sure to come into greater prominence. But the simulated results will have to be proved on the supply system itself, by tests on the larger machines. These sets and the system they feed will also be called into play for another very important function, which is that of training operators on the turbo-generator floor to revise their existing concepts of the difference between stable and abnormal operating conditions. This thought must have been in the mind of many of those who saw the impressive film that accompanied the I.E.E. paper by Mason and his colleagues. The film showed several sequences of a number of instruments on a turbo-generator panel during tests of asynchronous operation—a mundane subject perhaps : but there was nothing mundane about the violent oscillations of the dial pointers during the tests. Turbine operators may not find it easy to learn to interpret these alarming manifestations as symptoms of "abnormal," but safe and, within limits, tolerable operating conditions !

HOW TO SEE WORKS ABROAD

Quite a number of engineering firms in this country have recognised the advantage of sending executives, outstanding apprentices and others, abroad to see how other nations set about solving design, production and administrative problems. But though quite a number of travelling scholarships are available, and occasionally it is possible to organise Continental tours for works parties, opportunities are in fact few and far between even for executives to get abroad, far less employees from the shop floor. How many engineering executives, for example, can claim that their visits to works abroad in a whole lifetime are likely to exceed a number which can be counted on one hand ? As for the shop floor employee the probability is that unless military service takes him abroad he will never leave this country at all. The point has been recognised by a non-profit making body, Y.T.C. Universal, Ltd.,* which was formed seven years ago in Liverpool, having as one of its objects the fostering of international friendships and which has organised holidays abroad for large numbers of people. It is now setting up a special Division of its activities to be called Industrial Travel whose object it will be to organise visits by parties of people from industrial firms in this country to similar firms abroad. Suitable firms have been contacted in Holland, Luxembourg, Germany, Switzerland and Italy. In some instances parties of people from this country will not only be shown around the works abroad but enabled to meet the employees of the works outside working hours in sports clubs and canteens. It may even prove possible, we gather, especially where arrangements can be made on a reciprocal basis, for members of parties to be received into the homes of their opposite numbers abroad. We applaud the whole idea.

* 62, Hope Street, Liverpool, 2.

THE MIRACLE OF STANDARDS MAKING

Everybody applauds standardisation in principle, but not in practice if it means any trouble to himself. The same basic principle affects those who draw up a British Standard. Every manufacturer who learns that there is a proposal to create a standard relating to any of his products hastens to be represented on the committee concerned, for he naturally has the aim of getting his own standards adopted as British Standards, in which case he will not be inconvenienced by national standardisation. When a committee first meets, therefore, it is likely to be composed partly of self-interested members pulling each in a different direction, partly of earnest souls who are innocently striving for rational solutions and partly of people who are indifferent about what is done about the majority of items because their main interest is in particular ones. One cannot affect to be surprised if the product of such a coterie is long delayed and not entirely rational because it is really rather remarkable that agreement is eventually reached at all ! Yet much more frequently than not it is reached, although cynically one may suspect that agreement was at length attained only because a sufficiently large proportion of the committee members had become so wearied by prolonged wrangling as to abandon all pretence of further interest. One might imagine from the semi-legal character of the wording in many British standard specifications that the deliberations that produced them were comparably precise. Sometimes they are. For committees are just about as variable in character as people. It is more frequent, however, for discussions to be vague rather than rigorous, diffuse, and often off the point. Moreover, if a reasonable proposal is felt by a committee member to be unwelcome to his firm then he may feel driven by loyalty to that firm to parade all the outworn artifices for attempting to evade a straight answer as to why he objects to it. Some of his fellow committee men appreciating what he is about may derive a wry kind of light relief from assessing his skill at this performance. Any such relief is specially appreciated against the grey background of the long and usually unexciting deliberations that are inseparable from technical standardisation. But what really slows things down even more than the inevitable gradualness of drawing a number of individual minds into agreement is the periodic need for someone to do something instead of merely talking about it. To prepare a new draft of a specification, only partly agreed already, it may be necessary to examine the minutes in order to try to make sense out of proposals, agreed in the past, which turn out to be conflicting in the present ; to make calculations, and to prepare drawings. This work is usually done by a committee member (or his staff) as an unrewarded

addition to his normal duties. It cannot be given high priority. The "atom" of time for it is usually three months or so. Very often the volunteer must sadly say that it may take six months and would it not be more efficient to accept his own standard which he can let the committee have to-morrow? Failing the alternative (which is rarely accepted) the years may roll by so that when a standard is eventually published the committee nominally responsible for it may include but few of the original members.

But if those who have served on B.S. committees sometimes come away from meetings acidulated, convinced that time has been unnecessarily wasted, believing that certain members have been deliberately obstructive and, in fact, in a very bad frame of mind indeed, any who have served for long gain an admiration for the secretaries who patiently and not without acquired skill slowly jolly committees along towards agreement. Secretaries, we suspect, never dare make a really verbatim report about a meeting. For it would be tactless in the extreme to reveal to members what they really said, which accounts no doubt for the little use made by committees of tape recording instruments. But they do try to record salient points. We suspect the contestants themselves often recognise less clearly than the secretaries how salient were the points under discussion or even that there was a salient point under discussion at all! In general secretaries succeed wonderfully well, but each must often feel that the final result—a British Standard—gives a very poor impression of the work that he had to do to get a committee to produce any coherent result at all. The ordinary purchaser of a British Standard can have no inkling of the nature or duration of the committee vicissitudes behind it, but anyone who has lived through even one period of gestation must always marvel at the miracle of birth.

ENGINEERING INDUSTRIAL RELATIONS

When, in the Spring of 1956, almost immediately after substantial wage increases had been agreed between the Engineering and Allied Employers' National Federation and the Amalgamated Engineering Union, the Union formulated yet another claim for a further "substantial increase in wages," the Federation took the unprecedented step of announcing publicly that a new wage claim would be resisted; and when the claim was submitted during the summer it was in fact rejected. Thereafter, the Federation, for months, refused to budge. The union leaders claimed indignantly that the employers were refusing to negotiate; tempers rose; and in March, 1957, there were official strikes in the shipbuilding and engineering industries. Thereafter, the Minister of Labour having intervened, the Federation made an offer, upon the basis of which and as a result of a hearing before a Court of Inquiry, the dispute was settled.

That piece of history, in addition to the fact that in 1954 a Court of Inquiry had also had to be set up to get a wage dispute settled, led to quite widespread criticism of the Federation and of the mechanism for settling disputes in the industry. Partly to answer those criticisms, the Federation has now published a brochure entitled "Looking at Industrial Relations." If those whose job it is to comment upon industrial affairs read what it has to say, it will certainly contribute towards a better general understanding of the real situation in the engineering industry. For the acrimony which crept into the negotiations during 1957 was quite unusual. The history of the relationship between the Federation, which was set up in 1896, and the unions, which from the beginning were recognised by the Federation, is for the most part happy; and the machinery for settling disputes has worked well. Before 1957 any kind of strike in support of a wage claim, even a token one, was a rarity. To quote from the brochure, "the engineering employers resisted the union demands in 1957 not so much because they could not find the money for a pay increase but because they believed, and the Government did too, that temporary wage restraint in an inflationary economy was essential in the national interest." The Federation feels it was let down by the Government. But, as the brochure points out, the 3,000,000 engineering workers who eventually benefited from a pay increase found within a very few months that more money could buy no more goods than before.

The Federation, according to the brochure, is depressingly convinced that no one has learnt any lessons from the event. That may be so. But the struggle between the Federation and the union has, we suggest, cleared the air, like that of 1897, which involved the question of workshop control and the limits of trade union interference in management, of 1922 which again involved the right of employers to manage their own factories, and of 1919—an unofficial affair—which was concerned with the powers of shop stewards. As so often happens in human relations, heat is not generated so much by the existence of a difference of opinion as by a wholly unexpected reaction upon one side or the other. Union leaders had become so accustomed annually to making a claim and receiving in return from the Federation a counter-offer that it proved inexpressibly shocking to them when the Federation refused to make an offer at all. The union leaders now know that under certain circumstances the Federation will prove ready to stand fast. In consequence, reasonable and less inflationary settlements of wage claims may be easier to reach in the future.

The Engineer—100 Years Ago (FEBRUARY 11, 1859)

"Highways in England"

"Mr. Hardy, in moving for leave to bring in a bill for the better management of highways in England, said that the evils of the present management of highways were so notorious, and had been so often admitted in the House, that he thought he should best consult the convenience of the House by waiting for the discussion with regard to the means of remedying them when the bill was in hon. members' hands. Mr. Philipps was of opinion that it would be a necessary preliminary to legislation upon the subject that the House should define what a highway really was, seeing that legal decisions relating thereto were most conflicting, and there was great difficulty in ascertaining what it meant. In fact, the only method of establishing whether a public road was a highway or not was the process of indictment. By giving a definition of what a highway was, then a good foundation would be laid for future legislation."

"Granite Wheel-Tracks"

"Mr. D. F. Walker again urges the adoption of his plan of laying down granite lines for wheel carriages to run upon, as successfully tried in Friday-street, Cheapside, and the Commercial-road, London, up Reigate-hill, and on the Corse at Milan. He believes that the great economy of wear and tear in horses, the decreased number wanted, the application to the growth of wheat of part of the land now used for horse-food, and the decrease of dust and dirt, would make it profitable to adopt the scheme not only in towns but on the roads generally. He says if granite be too expensive, large blocks of semi-vitrified clay or other hard substance might do."

Accurate Speed-Torque Tracer for Electric Motor Testing

By D. KARO, Dr. Eng., Ph.D., B.Sc., Dipl. Eng., M.I.E.E.*

An inexpensive, reliable and accurate speed-torque curve tracer† suitable for electric motors and many prime movers is described here. A high-frequency, simple generator, of low internal impedance and generating a sufficient voltage is used. The low internal impedance allows a fairly constant output voltage at all speeds ; this voltage is high enough not to require high gain d.c. amplification, avoiding thereby drift and rapid shifts in the output of the amplifiers. The output of the generator is through one circuit, rectified, suitably filtered and applied to the X plates of a cathode-ray oscillograph. With the aid of another circuit the output is rectified, differentiated, filtered and applied to the Y plates. The resultant display is a speed-acceleration curve and since the load is purely inertia, the curve is also a speed-torque curve. In comparative tests with dynamometer methods good agreement was obtained.

THE need for an accurate and rapid method of obtaining the speed-torque curves (average torque at constant speed) of electric motors arises from the fact that the usual dynamometer methods are slow and, therefore, very much conducive to errors due to overheating of the motor ; in addition, small and rapid torque variations, as well as the so-called unstable parts of the speed-torque curves, are impossible to obtain. A number of devices have been described fairly recently,‡ which allow the speed-torque curve of a motor to be obtained on a cathode-ray oscilloscope, whilst the motor is accelerating from rest to no-load speed. In all devices an electrical signal proportional to speed is applied to the *X* plates of the c.r.o. whilst the same signal differentiated, hence proportional to acceleration, is applied to the *Y* plates. The resulting trace is therefore a speed-acceleration curve and since with only an inertia load the motor acceleration is proportional to the output torque, this curve is also the speed-torque curve.

To obtain the speed signal, the devices mentioned use a tachometer (d.c. or a.c.) generator or a homopolar d.c. generator, either being driven by the motor to be tested ; there are also systems using pulses at a rate proportional to the motor speed, these pulses being then converted to a d.c. voltage proportional to the pulse rate.

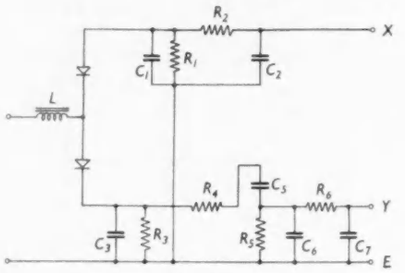
That the heteropolar d.c. generator is not suitable is immediately obvious. The commutator ripple, brush chattering and possible sparking will mask the phenomena to be displayed.

Major reduction of brush chatter and sparking is possible only by a very careful construction ; but filtering their effects (if any remain) is very difficult indeed, if not impossible. The speed of the generator varies from rest to the no-load speed of the tested motor; the effects to be filtered out are therefore contained in an extremely wide frequency band, almost certainly containing some of the phenomena to be observed.

Similarly, the filtering of the commutator ripple is almost impossible, the generator has to be small, hence it must have a small number of commutator segments; the ripple will then vary from a few to several hundred cycles per second. In addition, there is brush friction, which spoils the concept of a pure inertia load. The homopolar d.c. generator, although free from commutator ripple, may and often does suffer from brush chatter and sparking.

To overcome these difficulties, the sliding brush contacts have to be extremely well constructed, the rim of the rotor and the slipring made of polished silver and the brushes of silver graphite. This obviously increases the cost of the generator and limits its availability, since repolishing and cleaning is often necessary.

The greatest disadvantage of the homopolar generator is, however, the low d.c. voltage generated at the usual test speeds.



Fig, 3

In consequence, considerable amplification is necessary requiring, in general, one amplifier for the speed signal and two for the torque signal.

All the amplifiers are d.c. amplifiers, hence subject to slow drift and rapid shift in their output, the more so the greater their gain. Whilst the slow drift can, to a certain extent, be overcome by the use of selected tubes, regulated power supplies and proper ventilation, the rapid shift in the output presents a much more serious problem, since such shifts may happen at the precise moment when a test is made, making the interpretation of the results impossible.

A.c. tachometer generators of the permanent magnet rotor type are free from sliding contact trouble, they also produce a fairly high voltage which, when rectified and filtered, can, with little or no amplification, produce a reasonable movement of the spot of a c.r.o.; their disadvantages are, however, their high internal impedance and the low frequency of the generated voltage. The high internal impedance, which, in addition, varies with the speed, will produce a considerable and variable drop in the output ; this will, of course, adversely affect the reliability of the trace. The low frequency—hence high periodicity—may be dangerously

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† Patent applied for.

‡ "An Improved Electronic Speed-Torque Computer," J. M. Shulman and H. W. Hansen. *A.I.E.E.*, May 4–6, 1955 ; "Speed Torque Curves on an Oscilloscope," S. Chang. *Electrical Manufacturing*, September, 1950, pages 452–456 ; "Induction Motor Torque and its Measurement," E. W. Henderson and K. M. Chirgwin. *The Engineering Journal*, November, 1953 ; "A Dynamic Speed-Torque Curve Tracer for Motor Testing," K. J. Waldschmidt and H. P. Boettcher. *A.I.E.E.* April 16–18, 1956.

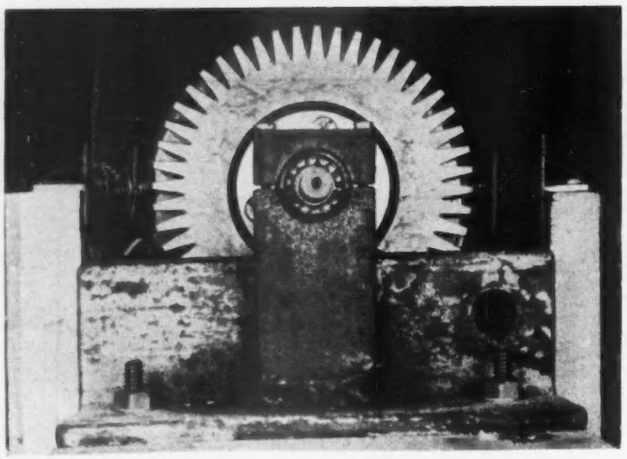

Fig. 1

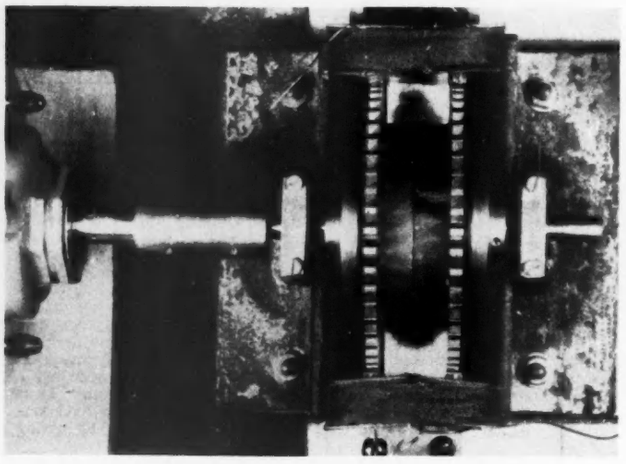

Fig. 2

near the periodicity of the observed phenomena ; no amount of careful filtering will be of any avail.

Speed-torque curve tracers using pulses require a large amount of electronic equipment such as squaring amplifiers, frequency doublers, multi-vibrators, integrating networks, cathode followers and at least three d.c. amplifiers. Obviously, the cost of the

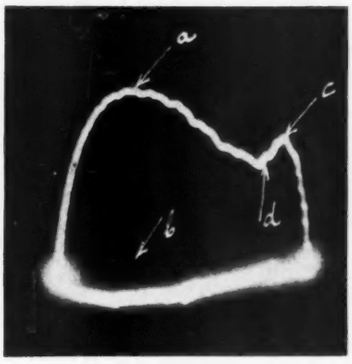

Fig. 4

equipment is prohibitive and the reliability, unless extreme care is taken, diminishes as the number of items in the equipment increases. It appears that the only solution possible, if one is to obtain the desired traces with not-too-expensive equipment and yet accurately and reliably, is to use a low-impedance high-frequency generator of a sufficient output voltage and driven by the tested motor.

The frequency has to be higher, at even the lowest speed, than that of any phenomena to be observed. The voltage should be high enough to require no d.c. amplifiers or, at most, to require low gain, stable d.c. amplification. The internal impedance of the

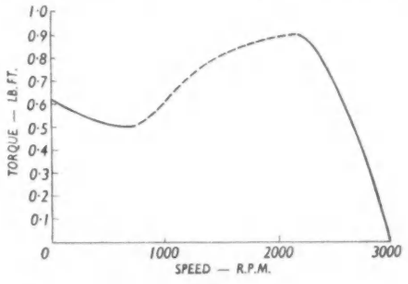

Fig. 5

generator should be low enough not to effect the output much in spite of its variation with speed.

The output of the generator will be rectified and suitably filtered for the speed signal, it will also be rectified, differentiated and suitably filtered for the torque signal.

The High-Frequency Generator

The generator is shown in Figs. 1 and 2, which are almost self explanatory. A strong annular magnet (in this case two sintered magnets) is placed between two steel, toothed wheels. The magnetic path goes via the teeth through two or more pick-ups in the form of horse-shoes (made preferably of magnetic laminations). The pick-ups carry coils, suitably connected ; the electromotive force is generated in these coils. The number of teeth on each wheel is forty-eight and as one wheel constitutes entirely an N pole and the other an S pole the number of cycles per revolution will also be forty-eight. The periodicity corresponding to forty-eight cycles per revolution is smaller than that of any phenomena likely to occur in the torque variations of an electric motor (except the 100 c/s torque variations and some cogging torques where a very large number of slots are present) so that a comfortable margin exists between the cut-off frequency of the low-pass filters and the lowest frequency of the generator.

An advantage of this kind of generator is that it will always start from the same relative position—with horse-shoe pick-up facing teeth of wheels—since it will always stop at this position. The electromotive force of the generator when starting is therefore always the same, provided the starting torque does not vary.

Rectifying Filtering and Differentiating Circuits

The circuits are shown in Fig. 3. A single half-wave metal rectifier is used, the connection from the coil L going to the centre of the rectifier. In this way, besides the result-

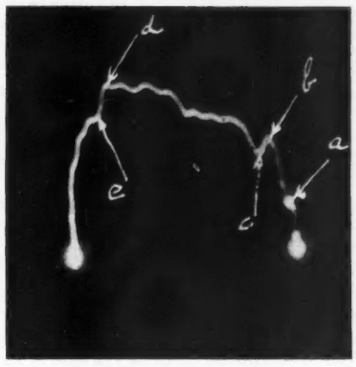

Fig. 6

ing saving of equipment there is the additional advantage that one half of the generator wave is used for the X plates circuit and the other half for the Y plates.

C_1, R_1, R_2, C_2 constitute the rectifying and filtering system for the X plates (speed signal). C_3, R_3 is the rectifying, R_4, C_5, R_5, the differentiating and C_6, R_6, C_7, the filtering system for the Y plates (torque signal).

The resistances R_1, R_2 and R_3 are variable so that the attenuation can be varied. For the X plate system the ripple attenuation is about 50 dB at 50 c/s and about 21 dB at 15 c/s. The attenuation values for the Y plate system are somewhat higher.

The values of the R_4, C_5 and R_5 are such that a differentiating accuracy of $\pm 0{\cdot}5$ per cent is obtained at 15 c/s and approximately $1{\cdot}5$ per cent at 50 c/s. R_5 can of course be variable if an increased accuracy is desired. The inductance L provides additional useful filtering and it has been found that the result was the same, whether two separate induct-

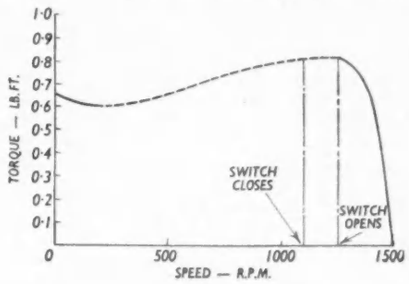

Fig. 7

ances were used, one for the X, the other for the Y system, or whether one was used for both systems. It was found that forward biasing of the rectifier was unnecessary, once a suitable one was chosen.

Calibration of C.R.O. and Associated Circuits

The speed signal was calibrated to an accuracy of about $0{\cdot}7$ per cent by means of a tachometer, the Y signal to an accuracy of

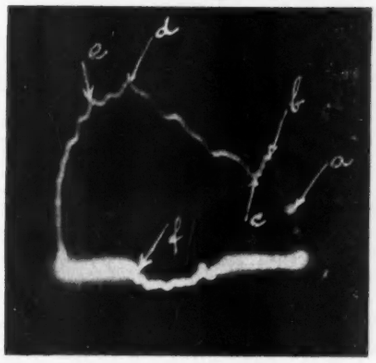

Fig. 8

about $0{\cdot}7$ per cent by means of a known torque. The known torque was provided by a calibrated weight attached to a string and wound on a load wheel placed on the shaft of the generator.

The calibration and testing of the circuit of Fig. 3 was made by means of a voltage rising at a constant rate. Let this voltage be $v=at$, where a is a constant and t denotes time, as $dv/dt=a$, this voltage will produce, when applied to the circuit supplying the Y plate, a constant amplitude deflection of the oscilloscope, during the rise time. The accuracy of differentiation is practically limited by the accuracy with which the oscilloscope could be read.

Results Obtained

Fig. 4 shows the speed-torque§ curve of a

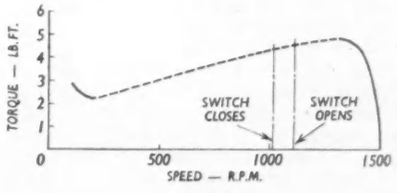

Fig. 9

¼ b.h.p. three-phase, 230V, two-pole motor with eighteen stator slots, thirty-two rotor slots; rotor slot skew, $0{\cdot}5$ stator slot. The overshoot at starting (c, Fig. 4) and the effect of seventh harmonic d are clearly visible. The torque pulsations from start to maximum torque agree with analytical descriptions of the phenomena.‖

The starting torque is about $0{\cdot}62$ lb ft, the maximum torque $0{\cdot}9$ lb ft occurring at 2300 r.p.m., a and b.

Fig. 5 shows the speed-torque curve obtained by a dynamometer method (full lines). The agreement with the trace on the oscilloscope is excellent.

Fig. 6 shows the speed-torque curve of a 1 b.h.p. single-phase, 230V, 50 c/s four-pole motor. The slot combination is thirty-six

§ In the photograph the x axis is reversed. the speed increasing from right to left.

‖ *Elektrische Maschinen*, R. Richter, Vol. IV., Verlag Birkhauser, Stuttgart, 1954, pages 190–194.

stator, forty-eight rotor, the rotor skew is equal to one rotor slot.

The overshoot *b* and the effect of a seventh harmonic *c* are clearly visible. There is also another harmonic present *a* the order of which is difficult to determine on so small a display.

The switch cutting off the auxiliary phase opens at about 1250 r.p.m. : the maximum torque on the main phase alone *e* is 8·3 lb ft at 1280 r.p.m.

The starting torque equals ~5·5 lb ft. Fig. 7 shows the speed-torque curve of the motor

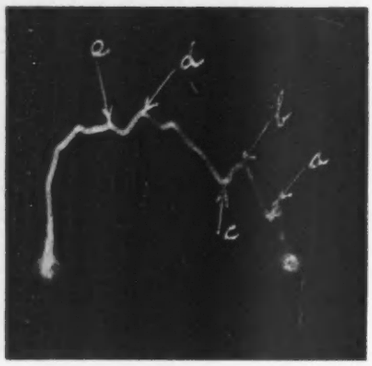

Fig. 10

obtained by means of an ordinary dynamometer. The results agree very well with those of Fig. 6 except near starting when it is difficult to obtain reliable and consistent results because of rapid overheating of the auxiliary phase.

Fig. 8 shows the speed-torque curve of a ½ b.h.p. 50 c/s, 230V, single-phase, four-pole motor. The slot combination is thirty-six stator, forty-eight rotor, skew of rotor 1·5 rotor slots.

Arrow *a* points to an overshoot and dip due to a high harmonic, *b* shows another overshoot and *c* a dip due to a fifth harmonic. The switch opens at about 1100 r.p.m. *d* and closes at about 1020 r.p.m. (*f* on the return trace). Arrow *e* marks the point of maximum torque ~4·8 lb ft at 1300 r.p.m. The results except for the points near zero speed agree well with the dynamometer test result shown in Fig. 9.

Fig. 10 shows the speed-torque curve of a ¼ b.h.p. 230V, 50 c/s, four-pole, single-phase motor, slot combination thirty-six stator, forty-eight rotor ; rotor slot skew, 1·5 rotor slots. The arrows point to phenomena similar to those in Fig. 8. Fig. 11 shows the

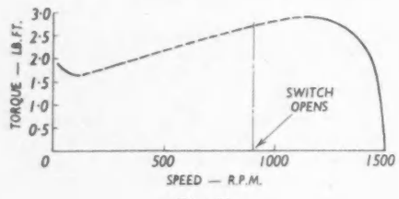

Fig. 11

result of a dynamometer test. Again there is good agreement with the trace shown in the photograph.

Acknowledgment

The author wishes to acknowledge with thanks the assistance rendered by his colleagues, Mr. S. L. Jones, A.C.T. (Birm.), A.M.I.E.E., and Mr. M. Jevons, B.Sc., A.C.T. (Birm.) in the testing of the equipment.

The Characteristic Method of Solution for the Problem of Plane Plastic Strain

By J. HALLING

The velocity and stress equations of plane plastic strain are hyperbolic linear partial differential equations. The article shows how the solution to such equations may be represented by series of characteristic curves which allow the determination of the stress and velocity conditions at all points in the deforming zone. The application of the method is demonstrated by its use in the study of the direct extrusion process. The theoretical solution for this process is compared with several results obtained experimentally using model materials whose mechanical properties approximate to the hypothetical plastic rigid material assumed in the theory.

THE forms of the equations of plane plastic strain are such that it is possible to obtain a solution to problems of this type using the method of characteristics. These characteristic curves, usually called slip or shear lines in this context, have definite geometric patterns associated with each type of problem. In a particular problem the solution will depend on the initial and boundary conditions which apply, and is obtained by iterative methods based on the properties of the characteristics. This type of problem has been dealt with, notably by Hill[1] and Prager,[2] who develop the properties of the characteristics by different methods.

Although the theoretical treatment demands certain simplifying assumptions with regard to the material properties, such assumptions do facilitate a complete stress and velocity solution to otherwise complex processes, e.g. sheet drawing, extrusion, hot rolling, &c.

The Stress Equations of Plane Plastic Strain

In these equations an isotropic plastic rigid material is assumed, so that they only strictly apply where the freedom of flow of the material is such that the elastic strains of the real material are negligible with respect to the plastic strains. Hence the transition regions in which, for a real material, the elastic and plastic strains are of comparable magnitude must be sufficiently narrow to satisfy the assumption of the hypothetical plastic rigid material. In any practical application of the following method the accuracy of the solution will depend on the degree of validity of the above assumptions in the particular instance.

In a condition of plane strain the flow is everywhere parallel to a single plane, in this case the *xy* plane, and is independent of the *z* direction. Although in most technological forming processes these conditions are seldom realised the discrepancy is sufficiently small for this technique to be widely applicable.

For conditions of plane strain,

$$\sigma_z=\sigma_3=\nu(\sigma_1+\sigma_2)=\nu(\sigma_x+\sigma_y) \quad . \quad . \quad (1)$$

For a plastic rigid material and assuming zero volume change Poisson's ratio has a value of 0·5.

Hence

$$\sigma_z=\sigma_3=\tfrac{1}{2}(\sigma_1+\sigma_2)=p \quad . \quad . \quad . \quad . \quad (2)$$

For reasons which will become apparent later, it is usual to designate the directions of the two planes of maximum shear in the *xy* plane by the terms " α line " and " β line." The anticlockwise rotation of the α line from the *x* direction is denoted by the angle ϕ. The angle θ represents the anticlockwise rotation of the direction of σ_1, the algebraically greater principal stress, from the *x* direction. The directions of the lines of maximum shear are conventionally designated α and β such that σ_1 bisects the first and third quadrants of the curvilinear coordinate system created by these α and β lines. Fig. 1 illustrates these conventions and also indicates the state of stress acting on a small curvilinear element. Fig. 2 shows the appropriate Mohr's circle diagram for this state of stress and it can be seen that *p* represents the mean compressive stress on the planes of maximum shear stress *k* and is also equal to σ_3. Thus each unit volume of the plastic material is subjected to a triaxial hydrostatic stress *p*, and a pure shear in the *xy* plane of value *k*. The value of *k* is given by $\frac{Y}{2}$ according to the Maximum Shear Stress Criteria of yielding and by $\frac{Y}{\sqrt{3}}$ in the Distortion/Energy Criteria.

From Fig. 2 it is seen that

$$\left.\begin{aligned}\sigma_x&=-p-k\sin.\,2\phi\\ \sigma_y&=-p+k\sin.\,2\phi\\ \tau_{xy}&=k\cos 2\phi\end{aligned}\right\} \quad . \quad . \quad . \quad (3)$$

Notation

σ_x—Normal stress in the *x* direction of a Cartesian system.
σ_y—Normal stress in the *y* direction of a Cartesian system.
σ_z—Normal stress in the *z* direction of a Cartesian system.
τ_{xy}—Shear stress in the *xy* plane.
σ_1—Algebraically greater principal stress in the *xy* plane.
σ_2—Algebraically lesser principal stress in the *xy* plane.
σ_3—Intermediate principal stress.
k—Maximum shear stress in the material, i.e. for a plastically deforming mass k represents the yield stress in shear for the material.
Y—Yield stress of the material in uniaxial tension.
$\dot{e}_x$—Linear strain rate in the *x* direction.
$\dot{e}_y$—Linear strain rate in the *y* direction.
$\dot{e}_z$—Linear strain rate in the *z* direction.
$\dot{\gamma}_{xy}$—Shear strain rate in the *xy* plane.
$\dot{\gamma}$—Maximum shear strain rate.
θ—Angle between the direction of σ_1 and the *x* direction, measured anticlockwise.
ϕ—Anticlockwise rotation of one plane of maximum shear from the *x* direction (see Fig. 1).
ν—Poisson's ratio.
u_x—Velocity component in the *x* direction.
v_y—Velocity component in the *y* direction.
p—Mean compressive stress on the planes of maximum shear.
α—Denotes one family of physical plane characteristic curves referred to as α slip lines.
β—Denotes the other family of physical plane characteristics —the β slip lines.
α′—Denotes the family of hodograph plane characteristic which correspond with the α slip lines.
β′—Denotes the other family of hodograph plane characteristics corresponding to the β slip lines.
u—Velocity component along the α lines.
v—Velocity component along the β lines.
W—Rate of plastic work per unit volume.
R—Radius of curvature of an α physical plane characteristic.
S—Radius of curvature of a β physical plane characteristic.
R'—Radius of curvature of an α′ hodograph plane characteristic.
S'—Radius of curvature of a β′ hodograph plane characteristic.

In the absence of body forces the equations of equilibrium for conditions of plane strain are

$$\frac{\partial \sigma_x}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}=0=\frac{\partial \sigma_y}{\partial y}+\frac{\partial \tau_{xy}}{\partial x} \quad . \quad . \quad . \quad (4)$$

It is convenient to transform these stress equations into terms of p, k and ϕ by using equations (3), hence obtaining equations (6) below. If p and ϕ are continuous functions

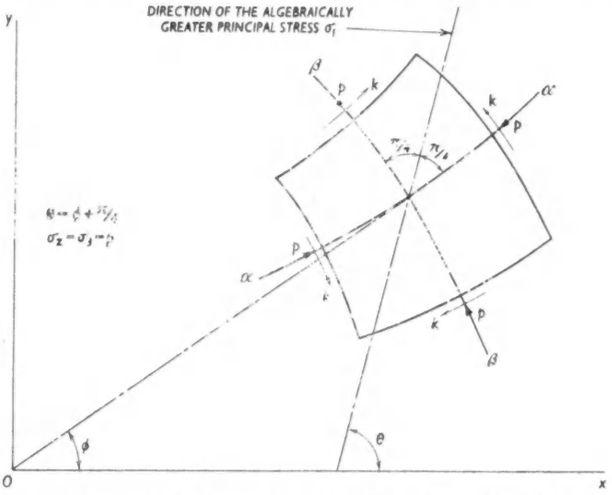

Fig. 1—The stress conditions and the conventions used, for the solution of problems in plane plastic strain

of x and y, i.e. no stress discontinuities (the possibility of such discontinuities is mentioned later), then:

$$\left.\begin{aligned} dx\frac{\partial p}{\partial x}+dy\frac{\partial p}{\partial y} &= dp \\ dx\frac{\partial \phi}{\partial x}+dy\frac{\partial \phi}{\partial y} &= d\phi \end{aligned}\right\} \quad . \quad (5)$$

And,

$$\left.\begin{aligned} -\frac{\partial p}{\partial x}-2k\cos 2\phi\frac{\partial \phi}{\partial x}-2k\sin 2\phi\frac{\partial \phi}{\partial y} &= 0 \\ -\frac{\partial p}{\partial y}+2k\sin 2\phi\frac{\partial \phi}{\partial x}+2k\cos 2\phi\frac{\partial \phi}{\partial y} &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Equations (5) and (6) are a series of four simultaneous algebraic equations in the variables $\partial p/\partial x$, $\partial p/\partial y$, $\partial \phi/\partial x$, $\partial \phi/\partial y$ and may be solved accordingly for each of these derivatives.

Solving for $\partial p/\partial x$ and using determinant notation gives

$$\frac{\partial p}{\partial x}=\frac{\begin{vmatrix} dy & 0 & 0 & -dp \\ 0 & dx & dy & -d\phi \\ 0 & -2k\cos 2\phi & -2k\sin 2\phi & 0 \\ -1 & -2k\sin 2\phi & +2k\cos 2\phi & 0 \end{vmatrix}}{\begin{vmatrix} dx & dy & 0 & 0 \\ 0 & 0 & dx & dy \\ -1 & 0 & -2k\cos 2\phi & -2k\sin 2\phi \\ 0 & -1 & -2k\sin 2\phi & +2k\cos 2\phi \end{vmatrix}}$$

Therefore

$$\frac{\partial p}{\partial x}=\frac{\begin{aligned} &dy[-d\phi(-4k^2\cos^2 2\phi-4k^2\sin^2 2\phi)] \\ &+dp[-dx(-2k\sin 2\phi)+dy(-2k\cos 2\phi)] \end{aligned}}{\begin{aligned} &dx[dx(2k\sin 2\phi)+dy(-2k\cos 2\phi)] \\ &-dy[dx(2k\cos 2\phi)+dy(2k\sin 2\phi)] \end{aligned}}$$

$$=\frac{Z}{N} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Three possible types of solution to this equation are :

(*a*) If $N\neq 0$ the value of $\partial p/\partial x$ is uniquely determined. In a similar fashion the other derivatives would be determinate and the solution could be extended throughout the system considered.

(*b*) If $N=0$ and $Z\neq 0$ the values of the derivatives are infinite and a solution may not be continued.

(*c*) If $N=0$ and $Z=0$ the values of the derivatives are indeterminate and they may also be discontinuous. The meaning of this condition is best illustrated by considering a plastically deforming region such that the complete solution is known on one side of some curve AA. In this case, where the derivatives defined by equation (7) are indeterminate, the solution cannot be extended beyond AA unless additional information is available for such extension. In such circumstances the curve AA is termed a characteristic and the conditions for such characteristics may be obtained by placing the numerator and denominator of equation (7) each equal to zero. Putting $N=0$ in equation (7) yields the slope conditions for these characteristics whilst putting $Z=0$ produces the relationship between the variables p and ϕ.

Physical Plane Characteristics

Equating the denominator of equation (7) to zero produces the quadratic equation,

$$\left(\frac{dy}{dx}\right)^2+2\cot 2\phi\,.\left(\frac{dy}{dx}\right)-1=0 \quad . \quad . \quad (8)$$

Hence,

$$\left(\frac{dy}{dx}\right)=-\cot 2\phi\pm\operatorname{cosec} 2\phi.$$

Thus the slopes of the physical plane characteristics are:—

$$\left(\frac{dy}{dx}\right)_\alpha=\tan\phi \text{ and } \left(\frac{dy}{dx}\right)_\beta=-\cot\phi \quad . \quad (9)$$

Hence the physical plane characteristics, designated α and β lines respectively, are a series of orthogonal curves whose directions are along the direction of the maximum shear stress k. The convention for designating the α and β characteristics, often called slip lines or shear lines, has already been anticipated and illustrated in Fig. 1.

Stress Equations Holding Along the Slip Lines

Equating the numerator of equation (7) to zero gives,

$$\frac{dp}{d\phi}=\frac{2k\left(\frac{dy}{dx}\right)}{\cos 2\phi\left(\frac{dy}{dx}\right)-\sin 2\phi}.$$

The slope of the physical plane characteristics (dy/dx) has the alternative orthogonal values given by equations (9).

Hence

$$\left.\begin{aligned} &\frac{dp}{d\phi}=-2k \text{ for } \left(\frac{dy}{dx}\right)_\alpha=\tan\phi \\ &\text{and} \\ &\frac{dp}{d\phi}=+2k \text{ for } \left(\frac{dy}{dx}\right)_\beta=-\cot\phi \end{aligned}\right\} \quad . \quad (10)$$

Equations (10) therefore, yields a condition for another set of characteristics which would consist of a series of orthogonal straight lines of slope $+2k$ and $-2k$. These might be called the stress plane characteristics. Because of the simple form of equations (10) it is not usual to draw the stress plane characteristics but, rather, these equations are integrated yielding the compatibility conditions holding along the respective physical plane characteristics.

Thus

$$\left.\begin{aligned} &p+2k\,.\,\phi=\text{a constant along the } \alpha \text{ lines} \\ &p-2k\,.\,\phi=\text{a constant along the } \beta \text{ lines} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

These equations were originally derived by Hencky[3] who referred the equilibrium equations to the slip lines as a set of curvilinear co-ordinates, i.e. these equations are a restatement of the equilibrium equations.

Prager[2] has shown certain geometric relationships between the stress conditions as represented by the Mohr's circle diagram, which are in effect a further representation of equations (10).

Writing equation (8) in a general form,

$$A\left(\frac{dy}{dx}\right)^2+B\left(\frac{dy}{dx}\right)+C=0.$$

This equation has three types of solution:

(*a*) $B^2>4AC$; i.e. the governing partial differential equations are hyperbolic and the solution to equation (8) yields a set of real

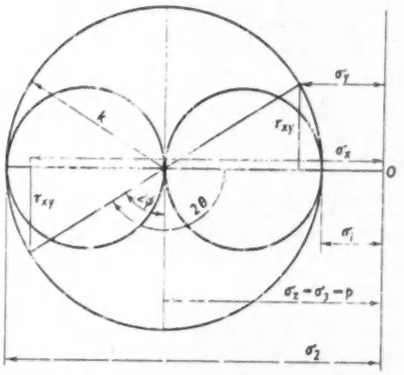

Fig. 2—Mohr's circle diagram for the stress condition of plane plastic strain

physical plane characteristics, slip lines, and the compatibility conditions, equations (11).

(*b*) $B^2=4AC$; this gives one real root indicating the parabolic nature of the governing equations.

(*c*) $B^2<4AC$; this gives no real roots so that the characteristics are imaginary and the governing equations are elliptic.

We thus conclude that the stress equations of plane plastic strain are hyperbolic and their solution may be represented by real characteristics curves, slip lines, with certain stress relationships holding along these lines.

The Stress Solution of Problems in Plane Plastic Strain

In a particular deformation process it is probable that the form of the solution of the governing equations will be different in various regions of the plastically deforming mass, e.g. a region of uniform stress distribution may adjoin a region of non-uniform distribution. These different regions would, therefore, have geometric properties of the physical plane characteristics which corresponded to the appropriate solution. Furthermore, these various regions would be joined along a characteristic which is common to

both regions and along which the necessary discontinuities of the derivatives can exist. (The possibility of the discontinuity of the derivatives along the characteristics was mentioned in relation to the properties of equation (7), i.e. along a characteristic the derivatives are indeterminate and may be discontinuous.)

Some common geometric forms of the orthogonal characteristic curves are shown in Fig. 3. Fig. 3 (*a*) shows a general form of orthogonal network constructed on the basis of the two curves *OA* and *OB*. If the curve *OA* is of zero length this pattern is a fan as shown in Fig. 3 (*b*), whilst if the curve *OA* is a straight line then the other family of curves, *OB*, &c., must be either involutes or circular arcs, Fig. 3 (*c*). If the curve *OB* is straight the pattern is a fan of straight lines and circular arcs as shown in Fig. 3 (*d*). Fig. 3 (*e*) results when both families of characteristics are straight lines and since ϕ must therefore be constant throughout this system it is seen, from equations (11), to represent a system of

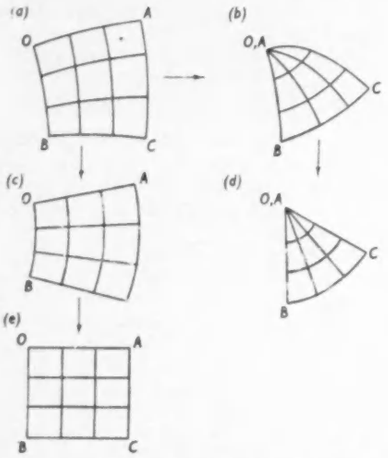

Fig. 3—Typical geometric forms of the slip line patterns

uniform stress distribution. Patterns of the type shown in Fig. 3 (*b*) and 3 (*d*) are commonly found at the edges or corners of dies and indenting tools.

The physical plane characteristics, or slip lines, for a particular process are thus found to occur in separate zones having distinct geometric properties, and joined along an appropriate characteristic which is common to adjoining regions. The pattern for sheet drawing with moderate reduction is shown in Fig. 4 and four distinct zones are readily appraised. The region *ABC* will be seen to be one of uniform stress with fan-shaped regions *ACD* and *BCE* occurring at the die corners.

In general, in any particular deformation process it is not possible to build up the characteristic (slip line) pattern by an explicit method. It is necessary to build up the pattern on the basis of some assumed shape for a particular slip line such that this pattern unambiguously satisfies the appropriate boundary conditions. Some typical stress boundary conditions in terms of the relative angles of the slip lines are shown in Figs. 5, 6 and 7, together with the relevant Mohr's circle diagrams. In each case two possibilities exist depending on the designation of the two slip lines according to the convention illustrated in Fig. 1. Figs. 6 and 7 indicate the boundary conditions for the two limiting frictional conditions and other frictional conditions must lie between these two extremes.

The geometrical properties and the numerical calculation of characteristic patterns such as those illustrated in Figs. 3 and 4 have been classified by Hill.[1] He also indicates the usefulness of the curvature of the slip lines as a technique which facilitates calculation.

Velocity Equations of Plane Plastic Strain

In some problems the slip line field is uniquely determined by the stress considerations alone, the velocity boundary conditions being used to establish the velocity distribution. In other problems the complete solutions require that the stress and velocity boundary conditions must be considered together. Thus the validity of a slip line field is only established provided it satisfies both the stress and the velocity boundary conditions.

It is convenient to consider the process of continuous deformation as a quasi-static condition. The derivatives of the velocity components with respect to the co-ordinate directions then constitute strain rates, or strains occurring in unit time interval. Since $\dot{e}_z$ is zero the condition of zero volume change becomes

$$\dot{e}_x+\dot{e}_y=0$$

or

$$\frac{\partial u_x}{\partial x}+\frac{\partial v_y}{\partial y}=0 \quad . \quad . \quad . \quad . \quad (12)$$

For an isotropic material the axis of principal stress and principal strain rate coincide so that

$$\tan 2\theta=\frac{2\tau_{xy}}{\sigma_x-\sigma_y}=\frac{\dot{\gamma}_{xy}}{\dot{e}_x-\dot{e}_y}.$$

But

$$\tan 2\theta=-\cot 2\phi, \text{ e.g. see Fig. 1.}$$

Therefore

$$-\cot 2\phi=\frac{\dfrac{\partial u_x}{\partial y}+\dfrac{\partial v_y}{\partial x}}{\dfrac{\partial u_x}{\partial x}-\dfrac{\partial v_y}{\partial y}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

It is convenient to introduce a velocity function ψ which satisfies equation (12), i.e.

$$u_x=\frac{\partial\psi}{\partial y} \text{ and } v_y=-\frac{\partial\psi}{\partial x}. \quad . \quad . \quad . \quad (14)$$

Substituting from equations (14) in equation (13) yields equation (17) below.

Furthermore, the condition of continuity of the velocity components results in

$$\left.\begin{aligned} dx\frac{\partial u_x}{\partial x}+dy\frac{\partial u_x}{\partial y}&=du_x\\ dx\frac{\partial v_y}{\partial x}+dy\frac{\partial v_y}{\partial y}&=dv_y\end{aligned}\right\} \quad . \quad . \quad (15)$$

Substituting for the velocity components in terms of the derivatives of ψ gives

$$\left.\begin{aligned} dx\frac{\partial^2\psi}{\partial x\,.\,\partial y}+dy\frac{\partial^2\psi}{\partial y^2}&=d\left(\frac{\partial\psi}{\partial y}\right)\\ dx\frac{\partial^2\psi}{\partial x^2}+dy\frac{\partial^2\psi}{\partial x\,.\,\partial y}&=d\left(\frac{\partial\psi}{\partial x}\right)\end{aligned}\right\} \quad . \quad (16)$$

And

$$-\frac{\partial^2\psi}{\partial x^2}+2\cot 2\phi\frac{\partial^2\psi}{\partial x\,.\,\partial y}+\frac{\partial^2\psi}{\partial y^2}=0 \quad . \quad (17)$$

Taking equations (16) and (17) as a system of three linear simultaneous algebraic equations in the variables $\partial^2\psi/\partial x^2$, $\partial^2\psi/\partial y^2$ and $\partial^2\psi/\partial x\,.\,\partial y$ the solution for the latter term is written in determinant notation:

$$\frac{\partial^2\psi}{\partial x\,.\,\partial y}=\frac{\begin{vmatrix} 0 & dy & -d\left(\frac{\partial\psi}{\partial y}\right)\\ dx & 0 & -d\left(\frac{\partial\psi}{\partial x}\right)\\ -1 & 1 & 0\end{vmatrix}}{\begin{vmatrix} 0 & dx & dy\\ dx & dy & 0\\ -1 & 2\cot 2\phi & 1\end{vmatrix}}$$

$$=\frac{-dy\left[-d\left(\frac{\partial\psi}{\partial x}\right)\right]-d\left(\frac{\partial\psi}{\partial y}\right).dx}{-dx\,.\,dx+dy(dx\,.\,2\cot 2\phi+dy)}$$

$$=\frac{Z'}{N'} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

As was the case for the solution of the characteristics in the stress equations it is necessary to put Z' and N' each equal to zero in equation (18). The equation which then yields the physical plane characteristics for the velocity solution is, from the denominator of equation (18):

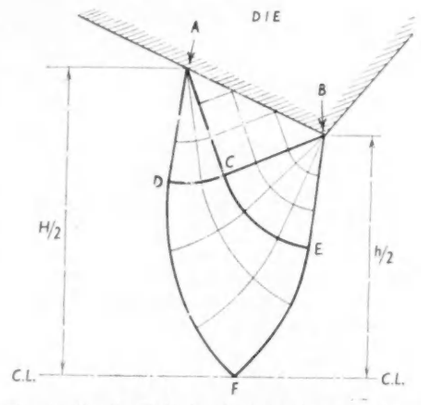

Fig. 4—Slip line field for sheet drawing through a smooth die with moderate reduction. (Pattern symmetrical about *C.L.*)

$$\left(\frac{dy}{dx}\right)^2+2\cot.2\phi\left(\frac{dy}{dx}\right)-1=0$$

i.e.

$$\left(\frac{dy}{dx}\right)_\alpha=\tan.\phi \text{ and } \left(\frac{dy}{dx}\right)_\beta=-\cot.\phi. \quad (19)$$

Thus the physical plane characteristics for the velocity solution are identical with the physical plane characteristics (slip lines) of the stress solution.

Equating the numerator of equation (18) to zero gives

$$\frac{d\left(\frac{\partial\psi}{\partial y}\right)}{d\left(\frac{\partial\psi}{\partial x}\right)}=\frac{dy}{dx}$$

or, recalling equations (14),

$$\frac{dv_y}{du_x}\cdot\frac{dy}{dx}=-1 \quad . \quad . \quad . \quad . \quad (20)$$

It is, therefore, possible to construct a series of characteristics in a u_x, v_y plane, i.e. the hodograph characteristics, and such characteristics are at all points orthogonal to the corresponding physical plane characteristics (slip lines). If corresponding characteristics in the hodograph plane are designated α' and β' the slope of these characteristics is given by,

$$\left.\begin{aligned}\left(\frac{\partial v_y}{\partial u_x}\right)_{\alpha'}&=-\cot\phi\\ \left(\frac{\partial v_y}{\partial u_x}\right)_{\beta'}&=\tan\phi\end{aligned}\right\} \quad . \quad . \quad (21)$$

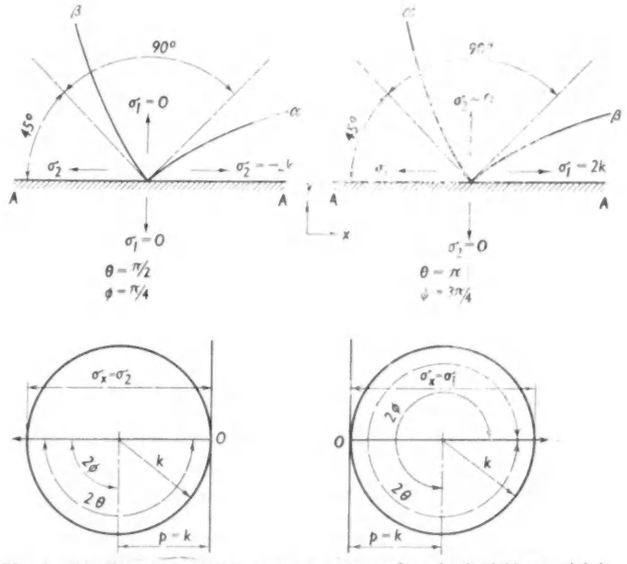

Fig. 5—Slip lines and stresses at the boundary of a plastic/rigid material in plane strain. The two possible conditions at a stress free surface *AA*.

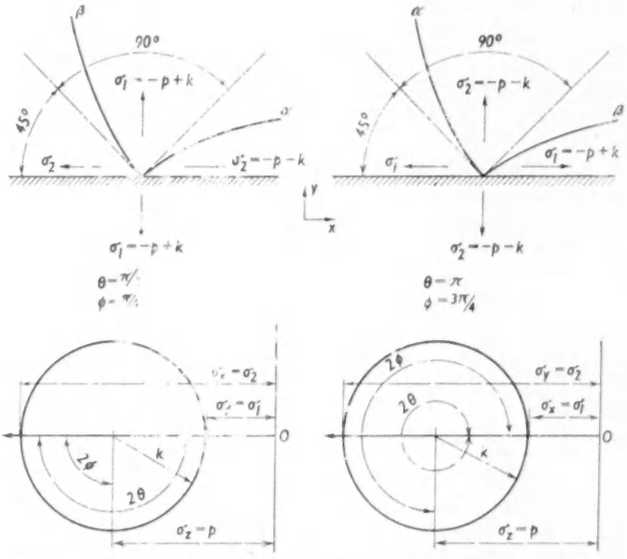

Fig. 6—Slip lines and stresses at the boundary of a plastic/rigid material in plane strain. The two possible conditions at the surface of a smooth rigid body

An alternative method of presenting equation (20) is to express it in the form of velocity conditions which hold along the slip lines. This is analogous to the method applied in the stress solution which resulted in Hencky's equations. For this purpose it is convenient to consider the velocity components along the slip lines rather than in the co-ordinate directions. If u and v represent the velocity components along the α and β lines respectively it follows from Fig. 1 that:

$$\left.\begin{aligned} u &= u_x \cos\phi + v_y \sin\phi \\ v &= v_y \cos\phi - u_x \sin\phi \end{aligned}\right\} \quad . \quad . \quad (22)$$

Considering the velocity relationships along an α slip line. From equation (21) it follows that:

$$\frac{dv_y}{du_x} = -\cot . \phi .$$

Hence

$$dv_y \sin\phi + du_x \cos\phi = 0.$$

Thus

$$\frac{dv_y}{d\phi}\sin\phi + \frac{du_x}{d\phi}\cos\phi = 0.$$

Adding $v_y \cos\phi - u_x \sin\phi$ to each side of this equation gives,

$$\frac{dv_y}{d\phi}\sin\phi + v_y\cos\phi + \frac{du_x}{d\phi}\cos\phi - u_x\sin\phi = v_y\cos\phi - u_x\sin\phi$$

or

$$\frac{d}{d\phi}(v_y \sin\phi + u_x\cos\phi) = v_y\cos\phi - u_x\sin\phi.$$

Substituting for u and v from equations (22),

$$\frac{du}{d\phi} = v$$

i.e.

$$\left.\begin{aligned} &du - v\,.\,d\phi = 0 \text{ along an } \alpha \text{ line} \\ \text{Similarly} \quad &dv + u\,.\,d\phi = 0 \text{ along a } \beta \text{ line} \end{aligned}\right\} \quad . \quad (23)$$

These equations were originally proposed by Geiringer.[4] They indicate that the extension along a slip line is zero which is also apparent from the orthogonal relationship between the slip lines and the hodograph characteristics as expressed by equation (20).

Equation (23) also shows that the velocity components are constant along a straight slip line. This case is illustrated in the hodograph diagram by a form of degenerate mapping: e.g. (*a*) If one family of slip lines are straight then all points along any straight slip line are represented by a single point in the hodograph. (*b*) If both sets of slip lines are straight in a particular region then such a region is represented by a single point in the hodograph, i.e. a region of uniform velocity.

Plastic Work

Having devised a slip line field with its associated hodograph diagram which satisfactorily fulfils the whole of the stress and velocity boundary conditions it is finally required to check that the plastic work at all points in this field is positive. The rate of plastic work $\dot{W}$ is computed from,

$$\dot{W} = k\,.\,\dot{\gamma} \quad . \quad . \quad . \quad . \quad (24)$$

where $\dot{\gamma}$, the maximum shear strain rate, is a function of the velocity derivatives at any point.

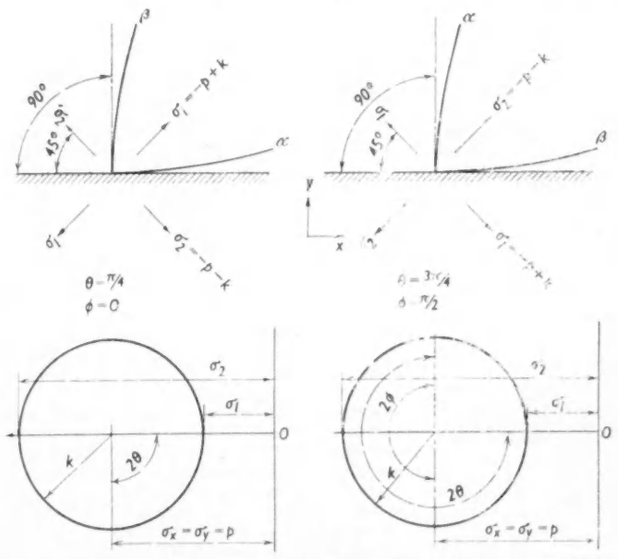

Fig. 7—Slip lines and stresses at the boundary of a plastic/rigid material in plane strain. The two possible conditions at the surface of a rough (sticking) rigid body

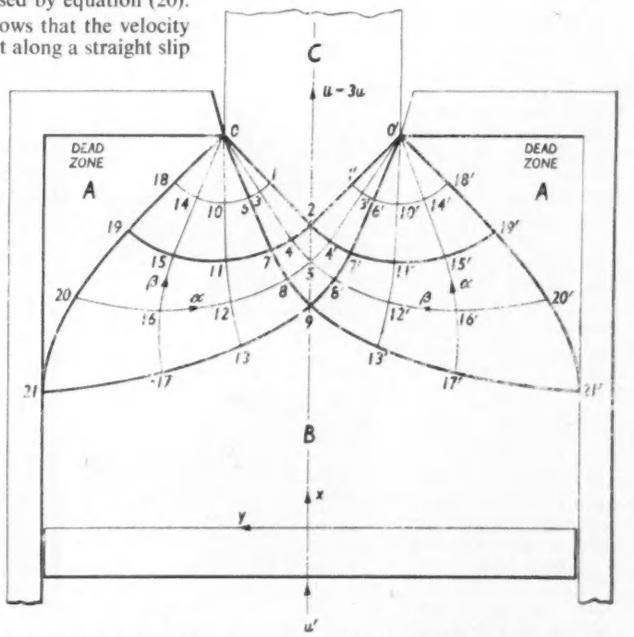

Fig. 8—The physical plane characteristics (slip line field) for direct extrusion with rough container walls and 66·7 per cent reduction

This check is facilitated by using the hodograph diagram as demonstrated by Green.[5] If R and S are the radii of curvature of the α and β slip lines and R' and S' are the radii of curvature of the respective hodograph characteristics ; then

$$\dot{W} = k\dot{\gamma} = k\left(\frac{S'}{S} - \frac{R'}{R}\right) \quad . \quad . \quad . \quad . \quad (25)$$

The positive nature of $\dot{W}$ is therefore checked by inspection of the slip lines and the corresponding point in the hodograph.

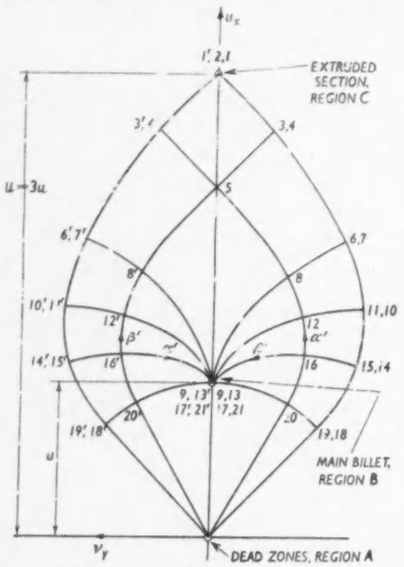

Fig. 9—The hodograph characteristics for direct extrusion with rough container walls and 66·7 per cent reduction

This technique may not be applied in the case of a situation where a tangential discontinuity in the velocity exists.

Stress and Velocity Discontinuities

The possibility of stress discontinuities cannot be ignored and has been considered by both Hill[1] and Prager.[6] It is not, however, such a frequent phenomenon as a discontinuity in the velocity. The normal component of velocity across a slip line must be continuous from considerations of the incompressibility of the material. Thus any discontinuity of the velocity can only occur in the tangential component of the velocity across a slip line. Hence a small element crossing the slip line is considered to undergo a sudden finite shear parallel to the discontinuity. In a practical case such a discontinuity is represented by a narrow transition region having a large shear strain rate.

Example of the Method

Consider the example of direct extrusion in plane strain when the walls of the container are rough and the reduction is 66·7 per cent. A satisfactory slip line field[7] is shown in Fig. 8. The dead zones B are a well-known phenomena in the extrusion process. (It is theoretically possible, and has been corroborated by experiments with model techniques,[8, 9] that with effective lubrication such dead zones do not occur.) The bounding slip lines 0, 18, 19, 20, 21 and 0′, 18′, 19′, 20′ and 21′ meet the container walls tangentially, i.e. the boundary condition shown in Fig. 7 when the maximum shear stress is tangential to the wall. The bounding slip lines 0, 1, 2; 0′, 1′, 2; 9, 13, 17, 21 and 9, 13′, 17′, 21′, meet the axis of symmetry at 45 deg., i.e. it is assumed that no stress discontinuity exists along this axis. The material outside the deforming region, defined by these bounding slip lines, is rigid, although it may be plastic. The thickened lines in Fig. 8 are those slip lines which are the boundaries of the several discrete regions which constitute the complete field.

The slip lines, 0, 1, 2 and 0′, 1′, 2, are straight, so that the stress at all points along such lines is constant. The resultant axial load in the extruded portion of the material must be zero. Hence by reference to the convention shown in Fig. 1 the slip line families may be designated α and β as shown in Fig. 8.

Fig. 9 shows the hodograph characteristics corresponding to the slip line field shown in Fig. 8. This has been constructed from the orthogonal relationships between α lines and α' lines, &c., established by equation (20) and the following velocity boundary conditions:

(*a*) The velocity of the extruded portion must be axial and for 66·7 per cent reduction have a magnitude three times that of the ram velocity, i.e. constancy of volume.

(*b*) There can be no normal component of velocity along the bounding slip lines 0, 18, 19, 20, 21 and 0′, 18′, 19′, 20′, 21′.

As a practical demonstration of the validity of this method several experimental results, for direct extrusion under these conditions, are shown in Fig. 10. Using the slip line field of Fig. 8 and its associated hodograph, Fig. 9, the resulting deformation to a square grid network may be calculated. Using a similar grid network scribed on a block which is subsequently extruded, the results obtained experimentally may be compared with the theoretical predictions. Fig. 10 shows typical results obtained using "Plasticine,"[8] lead and paraffin wax,[10] which are compared with the theoretical prediction. The model materials used in these tests have mechanical properties which approximate to the hypothetical plastic rigid material. Slight discrepancies in the patterns are due to this approximation and also differences in the frictional conditions at the container walls.

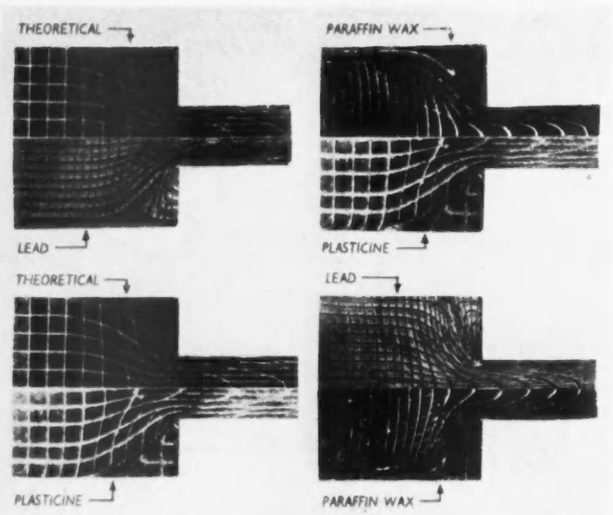

Fig. 10—Theoretical and experimental grid patterns for direct extrusion with rough container walls and 66·7 per cent reduction

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United Kingdom/Euratom Atomic Energy Agreement

The United Kingdom/Euratom Atomic Energy Agreement, the text of which was published as a White Paper last week, contains provisions for the exchange of information between the United Kingdom Atomic Energy Authority and the Euratom Commission, including the licensing and sub-licensing of patents. The agreement is intended to provide the necessary framework for practical co-operation on the peaceful uses of atomic energy between institutions and individual industrial concerns in the United Kingdom and in the Euratom countries. Thus, it will open the Euratom market to reactors developed in Great Britain and will help users in Euratom countries to gain experience in the field of natural uranium reactor technology. The Authority and the Commission are to assist persons within the Community and in the United Kingdom in obtaining research and power reactors and other material and equipment necessary for atomic energy programmes, and are to help them in obtaining assistance in the design, construction and operation of such reactors and of fuel manufacturing and processing plant. Arrangements are laid down for the supply by the Authority to the supply agency of the Community, or to other persons duly authorised by the Euratom Commission, of the necessary fuel for reactors obtained from the United Kingdom and for its processing after use. It is provided that the contracting parties shall co-operate in providing adequate financial protection against third party liability, and it is envisaged that the Atomic Energy Authority and the Euratom Commission may assist each other through the secondment of experts and in other ways.

There is an undertaking that material and equipment obtained under the agreement shall be used for peaceful purposes only. Moreover, the continuation of the co-operation envisaged in the agreement shall be contingent upon the mutually satisfactory application to such material and equipment (when it is within the European Atomic Energy Community) of the security control established under the provisions of the Euratom Treaty and (when it is within the United Kingdom) of the measures for accounting for the use of material and equipment established by H.M. Government. Consultation and exchanges of visits are to take place to implement this provision.

The agreement also provides for periodical meetings of representatives of the contracting parties to consult on matters arising out of the application of the agreement, to supervise its operation, and to discuss the possibility of additional arrangements for co-operation. Discussions have taken place recently between the members of the Commission and members of H.M. Government on the establishment of permanent machinery for this purpose. A standing committee will be established forthwith at the technical level and the parties agreed to consider further the question of establishing a supervisory body which would include members of the Commission on the one side and members of H.M. Government and of the Atomic Energy Authority on the other.

Experiments on the Compressive Strength of Anhydrite

By W. J. SKINNER, B.Sc.*

No. I

Anhydrite is not a material of which many engineers have experience. But much of the investigation described in this article is of more general application. In particular, the author points out that the theory might profitably be applied to concrete. Anhydrite (anhydrous calcium sulphate) is mined at the Billingham Works of Imperial Chemical Industries, Ltd., at an average depth of 800ft. About 20ft of the seam is extracted by the "pillar and stall" system, leaving, in the present workings, pillars 51ft square with intervening roadways 24ft wide; in a considerable area of older workings the pillars are 42ft square with 18ft roadways. The extraction ratio (ratio of stone won to total stone present in the thickness mined) is thus roughly 0·5 and, at a given depth, determines the compressive stress in the pillars. The choice of the ratio used was originally based on empirical mining experience. One of the chief factors determining the amount of stone which can be safely extracted is, obviously, the compressive strength of the pillars. In the interest of conservation of anhydrite reserves experiments were therefore carried out to obtain an estimate of the pillar compressive strength. A solution of this problem was obtained by the use of the theory of statistics of extreme values. The experiments and application of the results are therefore described in some detail since, although the statistical aspect of many fracture phenomena is now widely recognised, very few examples of application to practical problems are to be found in the literature.

As with most other brittle materials, the compressive strength of anhydrite decreases as the size of the specimen tested increases. This phenomenon, hereafter referred to as the size effect, is quite marked in anhydrite over the size range in which it is practicable to prepare and test specimens. As the maximum size of specimen of similar shape to a mine pillar (rectangular block of square cross section) which could be cut and crushed was *circa* 10in square considerable extrapolation of experimental results in terms of size was necessary to estimate pillar strengths. A major objective of this investigation was, therefore, to obtain a reliable relationship between size and strength for run-of-mine anhydrite.

This was complicated by the variable nature of the material and the resulting wide dispersion of strength. The anhydrite mined is a sedimentary rock with well-defined bedding. Its calcium sulphate content averages 90 per cent, but there are considerable fluctuations in purity, particularly in vertical section. It contains an average of 5 per cent of gypsum (a hydrated form of calcium sulphate) most of which occurs sporadically as relatively large crystals (porphyroblasts) set in the finer grained anhydrite matrix.

A further factor to be considered was the effect of specimen shape. As is well known, the compressive strength of specimens of constant cross-sectional area increases as the thickness (height) of the specimens decreases. It was, therefore, necessary to determine the effect of this factor at least over the range of pillar height/width ratios likely to be met in practice.

SOME THEORIES AND OBSERVATIONS OF BRITTLE FRACTURE

It is beyond the scope of this article to review all of the theories which have been proposed to explain the phenomena observed in the fracture of brittle materials. Only the general theories and some observations which are of particular interest in the present problem are therefore summarised below.

1. Effect of Specimen Size

(*a*) *General.*—When early work had indicated the marked effect of specimen size upon the compressive strength of anhydrite it was suggested that this was due to the increased incidence of macroscopic cracks and flaws in larger specimens. This suggestion was based upon the observation, made in preparing the specimens, that the difficulty of cutting blocks free from visible flaws increased with increasing size. It was supposed that these flaws were largely produced by blasting in the mine and that, apart from joints, the comparatively undisturbed centre of a pillar would be relatively free from such flaws. It was also thought that the large dispersion of the results from the early tests was attributable to variations in the magnitude of the cracks from one specimen to another.

However, the size effect is observed in many other materials and in various forms of strength tests. Examples are tensile tests on metal wires[1] and glass fibres,[2] compression tests on concrete and mortar[3, 4 and 5], bending tests on mortar beams[6] and notched bar tests on steels.[7] The variation of strength with size was, therefore, probably a more fundamental effect than suggested by the macroscopic flaw theory. Further reasons for rejecting the latter theory are given later.

(*b*) *Griffith's Theory.*—The theoretical cohesive strengths of solids, as derived from values of interatomic forces, are between two and three orders of magnitude greater than the observed strengths. In an investigation of the phenomena of rupture and flow in solids, Griffith[2] postulated that this discrepancy is due to the presence, in actual materials, of very small discontinuities or flaws. All subsequent theories of brittle fracture are based, either implicitly or explicitly, on this concept. Griffith also obtained a quantitative expression for the stress conditions under which a crack of given dimensions will become self-propagating and thus spread throughout the whole of the stressed body. His solution of this problem was based on the expression derived by Inglis[8] for the maximum stress at the ends of a transverse elliptical hole in a thin plate of isotropic material subjected to a uniformly applied tensile stress. Considering a crack as the limiting case in which the minor axis of an ellipse becomes vanishingly small, Griffith found that the overall stress S_0 under which a crack of length $2c$ spreads is† :

$$s_0 = \sqrt{\frac{2ET}{\pi c}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where E is Young's modulus and T is the specific surface energy, i.e. surface tension, of the material.

The validity of this equation was tested by breaking, under internal pressure, glass tubes and spheres containing cracks of various lengths produced by cutting with a diamond. It was found that the product $s_0\sqrt{c}$ remained substantially constant as predicted by equation (1). It was also shown, using measured values of E and T, that a crack or discontinuity 10^{-3}in long would be sufficient to decrease the tensile strength of the glass used from the theoretical value of *ca.* 3×10^6 lb per square inch to the value of 24,900 lb per square inch observed in tests on fibres 0·04in in diameter.

In considering the implications of the above theory, Griffith suggested that reduction of specimen size to very small values should lead to a material increase in strength owing to the limitation thus imposed on the maximum possible size of defect and that, therefore, the strength of indefinitely small specimens should approach the theoretical value. Tensile tests on glass fibres of diameters down to *ca.* 10^{-4}in showed that the observed strength did, in fact, approach the theoretical value.

So far, only the two-dimensional case of a crack in a thin plate subjected to a tensile stress acting in a direction perpendicular to the length of the crack has been considered. It is obvious that if, in this case, the stress is simply reversed so as to become compressive, there will be no tendency for the crack to spread since the effect of the applied stress is merely to force the sides of the crack together. It has been shown, however,[9] that in the three-dimensional case of uniaxial compression, the presence of internal cracks can still give rise to tensile stresses large enough for fracture to occur. Here, a similar relation between crack length and the overall stress required to propagate the crack holds (i.e. stress inversely proportional to square root of crack length) provided that the cracks in the isotropic material are oriented at random and that the maximum crack length, as well as the radius of curvature at the tip of the crack, is the same for all orientations.

(*c*) *The "Weakest Link" Concept.*—If it is assumed that numerous small defects are distributed throughout actual materials, it may also be assumed that a material body is made up of volume elements, each of which contains one defect. Different values of the overall stress will then be required to produce fracture in the individual volume elements which contain defects of different sizes. If the defects are distributed at random with a certain specific density and if it is assumed that each defect can propagate independently, the strength of the entire specimen will be determined by the weakest volume element, i.e. by the strength of the volume element containing the largest defect.

As a result of these considerations, the dependence of the strength of a specimen upon the strength of its weakest volume element has been likened to the simple case of a tensioned chain where the strength is determined by the strength of the weakest

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† If the thickness of the plate is large compared with $2c$, the overall stress which causes the crack to spread is

$$s_0 = \sqrt{\frac{2ET}{\pi c(1-p^2)}}$$

where p is Poisson's ratio. Since the difference between this value and that given by (1) is small and within the accuracy of (1) the simpler expression will be used here.

link. The formulation of the chain model appears to have been due to Peirce,[10] who used it to explain the variations of breaking strength with length observed in tensile tests on yarn and who realised the close connection of this problem with statistical theory. In terms of the weakest link concept, the strength of a chain will decrease with increasing length, i.e. with increasing number of links, owing to the greater probability of finding in long chains a weaker link than will be found in short ones. Statistically, the weakest link problem is thus equivalent to that of the distribution of smallest values in samples of a given size, where these are drawn at random from a parent population whose probability density function is known.

Generally, the distribution of the strengths of the hypothetical volume elements of actual materials is not known, and it is necessary to assume the form of this distribution to formulate quantitatively the expected relation between strength and size. In some cases, however, the distribution of the defect sizes can be inferred from observations other than strength determinations ; the strength distribution of the volume elements may then be calculated from equation (1). A further complication arises because it cannot always be assumed that the flaws are distributed throughout the volume of actual materials. In many brittle substances (e.g. glasses) the dangerous cracks are on the surface, so that their number cannot be proportional to the volume. but is more likely to be related to the surface area. As Orowan[11] has pointed out, any statistical treatment of brittle strength should therefore take into account the nature and history of the material.

2. Effect of Specimen Shape

As the pillars in the Billingham mine are mainly of square cross section, the only change of shape which was investigated was that of relative specimen height. In order to express shape quantitatively the term slenderness ratio is used, this being defined as the ratio of specimen height (thickness) to side length. (This should not be confused with the term used in connection with columns and struts, where slenderness ratio is defined as the ratio of height to least radius of gyration of the cross section.)

The general way in which the compressive

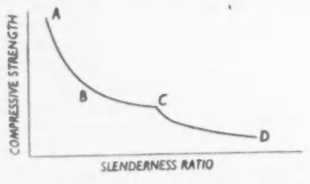

Fig. 1—Variation of compressive strength with slenderness ratio

strength of a brittle material varies with slenderness ratio is shown in Fig. 1.

The curve shown may be divided roughly into three parts, viz. *AB*, where the compressive strength decreases rapidly with increasing slenderness ratio merging into *BC*, an almost linear part of the curve with a small slope, followed by *CD*, where the rate of decrease of strength increases again after a discontinuity at *C*. To the right of *C* failure occurs by buckling and as *C* lies well above the range of slenderness ratios of interest in the present problem, the portion of the curve *CD* will not be considered further.

Since compression is an inefficient way of applying the tensile or shear stresses, or combination of these, which actually produce fracture, the slenderness ratio effect in the region *ABC* apparently arises from the influence of the specimen geometry on the orientation and intensity of these stresses. In other words, the change of strength with slenderness ratio may be regarded as a mechanical effect resulting from variation with shape of the mechanical advantage in the transformation of the applied compression to the tensile and/or shear stresses producing rupture. A knowledge of the actual mechanism is required to formulate the effect quantitatively. Numerous theories have been proposed, but there is still no general agreement as to the conditions which initiate fracture in compression even in isotropic materials. This, again, is probably due to some extent to variation of the mechanism of failure with the nature of the material, e.g. with the location of the most dangerous flaws.

The Griffith theory requires that fracture is produced by tensile stresses. The difficulty arises, however, that the most dangerous cracks in uniaxial compression would be those at 45 deg. to the stress and, in specimens with slenderness ratios appreciably greater than unity, these should propagate in their own plane. As is well known, failure in 45 deg. planes was also required by the much earlier theory of Coulomb, since this is the direction of the maximum shear stress. Fracture surfaces inclined at 45 deg. to the compression axis are rarely observed, however, the angle usually being greater than this while even vertical splitting is not uncommon. The theories of Navier and Mohr, according to which the inclination of the fracture plane is a function of the normal stress on that plane, while satisfactorily explaining the behaviour of some materials are not universally applicable and do not explain vertical splitting. By means of the ultrasonic pulse technique Jones[12] has shown that vertical cracks often develop in concrete specimens at stresses considerably below those at which failure ultimately occurs. Again, some materials which show inclined fracture surfaces when tested between dry compression plates, often split vertically if the plates are lubricated ; generally, lubrication of the compression plates results in a lowering of the critical stress. These observations indicate that the restraint exercised by friction at the compression surfaces may play a significant part in the shape effect and suggest that the stress conditions leading to fracture may vary with the testing technique.

EXPERIMENTAL PROCEDURE

In the investigation of the size effect the strength of specimens with dimensions varying from 10in by 10in by 6in to 0·15in by 0·15in by 0·045in was determined. As sources of error having little significance when testing large specimens assume major proportions when dealing with very small specimens it was found necessary to modify the methods of preparation and testing according to size as briefly described below. Except in one special case mentioned later, the specimens were oriented so that the compression faces were parallel to the bedding of the stone.

Specimen Preparation.—Specimens with side lengths of $\frac{1}{2}$in or more were cut from the parent stone to almost the required dimensions with a carborundum or diamond-impregnated wheel. They were then ground to final size on a steel plate with carborundum powder and water. Although nearly all of these larger specimens were subsequently crushed in presses provided with a ball joint which should theoretically compensate for non-parallelism of the compression faces, the opportunity was taken of eliminating this as a major source of error by grinding until the maximum departure from parallelism was 1 mil.

For the reasons given below, it was not practicable to use a ball joint to compensate for non-parallelism with smaller specimens, and thus it was essential to prepare these with their faces more accurately parallel. This was achieved by grinding a plate of anhydrite about 3in by 2in until the required thickness was reached and the maximum departure from parallelism in any direction was within 1 mil. The plate was then cut into squares and the resulting rough specimens mounted in an improvised jig for grinding to final size. The final grinding of $\frac{1}{4}$in specimens was carried out by piling a number of pieces with their compression faces adjacent, clamping them together and grinding the pile as a single unit. This reduced the time required for preparation and, more important, reduced the tendency for crystals of anhydrite to flake off from the edges and corners of the specimens. It was impracticable to grind the edges of still smaller specimens in this manner, however ; with these, the rough pieces were mounted in a row between two plates of " Perspex " and the plates and specimens were ground down together. It was necessary, of course, to repeat this process three times to grind all four edges of the specimens.

Compression Testing.—The testing of the larger specimens (1in side length and over) was straightforward and need not be described. Preliminary experiments with smaller specimens gave very variable and often low results even when the specimen faces had been made reasonably parallel as described above. This was found to be mainly due to two sources of error (eccentric loading and failure to apply the load over the whole of the specimen compression faces), which are considered in further detail below.

Axial Loading of Specimens.—In carrying out compression tests in a press fitted with a ball joint it is necessary to centre the specimens carefully so that the load is applied axially. A departure from the central position results in eccentric loading and if sufficiently great will cause the observed strength to be appreciably lower than the true value. The difficulty of centring the specimens and the effect of a given deviation increases with decreasing specimen size. This difficulty was enhanced in the present investigation since it was necessary to crush the smallest specimens in a Hounsfield Tensometer, in which the load is applied in a horizontal direction.

The simplest method of overcoming this difficulty was to eliminate the ball joint and arrange that the faces between which the specimens were crushed were always accurately parallel, since this would ensure that the load was applied axially even if the specimen was not accurately centred. Accordingly, a cylinder was made with two well-fitting pistons whose inner faces were ground accurately parallel, and the specimens were placed between the pistons for crushing. To avoid distortion and abrasion of the faces, the pistons were made of Cr-Mo steel, heat-treated to give a Brinell hardness of 500.

Local Loading of Specimens.—It was found that when the cylinder and pistons were used for crushing, some very low results were still obtained, particularly with the smallest specimens. This appeared to be due to failure to apply the load over the whole of the area of the compression faces owing to a slight tapering of the specimen thickness, sometimes at the edges, but mainly at the

corners, presumably due to the flaking off of crystals during grinding of the edges. The use of the finest grade of carborundum powder for grinding failed to correct this. The possibility that solution of anhydrite along the crystal boundaries, by the water used in grinding, caused these imperfections was also considered, but the use of paraffin

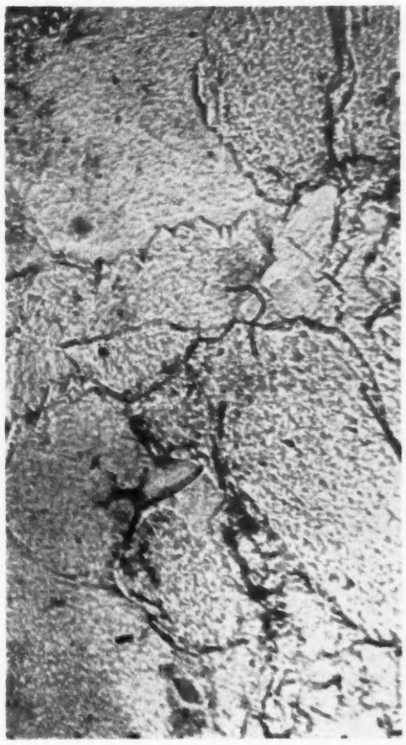

Fig. 2—Anhydrite 204. Very coarsely crystalline anhydrite from borehole core. ×140

instead of water as the grinding medium effected no improvement. The simplest method of overcoming this difficulty was the use of a deformable packing material in contact with the specimen to spread the load over the compression faces. This necessitated a careful choice of material since it is well known that readily deformable packing gives low results owing to the tearing apart of the specimens by tension resulting from lateral flow. It was found that the highest strengths were recorded when the packing consisted of a metal whose yield point was slightly lower than the ultimate specimen stress. The load was thus better distributed over the specimen area before failure by plastic flow of the metal. The resultant strain hardening increased the resistance to further flow so that the small stress increment then required to fracture the specimen caused little further deformation of the packing.

Mild steel was found to be a satisfactory packing material for most of the small specimens. Brass strip was used for an anhydrite sample with a very low compressive strength (ultimate stress *ca.* 6 tons per square inch), for, although this metal has no definite yield point, it flows slightly under loads of this magnitude and strain hardens.

This method of crushing could be criticised on the grounds that it probably altered the stress conditions at the specimen faces. The alternative of capping was considered to be open to similar objections.

Rate of Loading.—Owing to the use of a number of testing machines loading rates varied over the range 20 to 60 tons per square foot per minute.

EXPERIMENTAL INVESTIGATIONS

SIZE EFFECT IN ANHYDRITE OF CONSTANT QUALITY: (*a*) *Effect of Stone Quality on Strength.*—It is commonly observed that the strength of brittle crystalline materials decreases with increasing grain size. Experiments with samples drawn from a variety of sources to cover a large range of crystal size established that the compressive strength of anhydrite follows this general rule, as may be seen in Table I. For reasons which will become apparent a precise indication of crystal size cannot be given; the values shown are the approximate maximum crystal diameters observed in thin sections cut from the same horizon as the compression specimens. A better conception of the texture of the samples is given by Figs. 2 to 7, which are photomicrographs of the sections.

Fig. 3—Anhydrite 206. Very pure translucent anhydrite from mine. ×140

As impurities tend to reduce the crystal size there is also a rough correlation between strength and $CaSO_4$ content. Strong fine-grained stone is usually dolomitic, while the relatively weak coarsely crystalline stone has a low impurity content. The data in Table I suffice to show, however, that in the purer anhydrites the crystal size and, hence, strength, can vary independently of the chemical analysis.

(*b*) *Flaw Size Distribution.*—As the flaw sizes in most materials cannot be directly measured it is generally necessary to assume the form of the probability density function relating flaw size to frequency of occurrence before a relation can be derived for the

Fig. 4—Anhydrite 203. Fairly coarse anhydrite from borehole core. ×140

expected variation of strength with specimen size. Freudenthal[13] has pointed out that generally the probability of occurrence of a very large defect is unlikely to be the same as that for a very small defect, and this precludes the use of distribution functions which are symmetrical about their mean values. It is more consistent with observations to assume that the probability of occurrence of a flaw decreases with increasing size. It seems likely, therefore, that the probability density function $f(x)$ of the size of flaws will best be expressed by the simple Laplacian distribution:

$$f(x) = \lambda e^{-\lambda x} \quad . \quad . \quad . \quad . \quad (2)$$

where x denotes the flaw size and λ is a constant ($1/\lambda$ is the weighted average flaw size).

In the case of crystalline materials, the variation of strength with crystal size argues a close connection between flaw and crystal sizes and indicates that the maximum flaw size is determined by the maximum crystal dimension. The distribution of flaw and crystal sizes should, therefore, be similar. Where it is possible to determine crystal diameter over a wide range (i.e. in coarsely crystalline material) it has been found that the distribution in anhydrite is, in fact, of Laplacian form. This is illustrated in Fig. 8, which is a frequency histogram of crystal sizes for anhydrite 204.

In terms of the weakest link theory, therefore, the strength of a given specimen of anhydrite is determined by the size of the

TABLE I—*Effect of Crystal Size on Compressive Strength*

Specimen side length = 1in; slenderness ratio = 0·6 in all cases

Sample code No.	No. of specimens tested	Mean compressive strength (tons/ft²)	Range of observed strengths (tons/ft²)	Standard deviation (tons/ft²)	Approximate maximum crystal diameter (μ)	Chemical analysis of sample—per cent							
						SiO_2	R_2O_3	SO_3	$CaSO_4$	CaO	MgO	Loss on ignition	CO_2
204	4	840	770–950	81	500	0·2	0·2	57·0	96·9	40·6	0·4	0·5	—
206	4	1130	1050–1230	73	200	0·3	0·2	58·4	99·3	41·3	0·1	0·1	—
203	4	1490	1450–1510	29	150	0·1	0·1	57·1	97·0	41·1	0·4	1·1	—
205	4	1580	1510–1660	63	60	0·1	0·2	56·9	96·7	40·9	0·5	1·6	0·8
207	2	1860	1850–1870	14	60	0·2	0·2	57·9	98·4	41·0	0·2	0·3	—
208	3	2380	2300–2460	81	40	7·2	3·5	44·4	75·4	34·6	2·6	6·5	5·5

Fig. 5—Anhydrite 205. Fairly coarse anhydrite from borehole core. ×140

largest crystal it contains which is in the correct orientation to initiate fracture. The decrease in strength with increase of specimen size is then the result of the probability that larger crystals will be present in large specimens than in small ones.

It must be emphasised at this point that the above considerations of size distribution apply strictly only to anhydrite crystals. The largest crystals present in a good deal of the mine anhydrite are the gypsum porphyroblasts frequently reaching diameters of many millimetres. The large size, relatively sparse occurrence and perfect (010) cleavage of these crystals suggested the possibility that, where present, these were the effective

Fig. 6—Anhydrite 207. Pure flaggy anhydrite from mine. ×140

"stress raisers." Support for this view appeared to be given by the tendency in some tests for the strength of gypsiferous specimens to correlate with their density. On balance, however, the evidence, considered later, suggested that the porphyroblasts do not act as large flaws.

(*c*) *Expected Strength-Size Relation for Specimens of Constant Slenderness Ratio.*—It is shown in the Appendix that the mode, x_n^* (most probable value) of the largest value of x in samples containing n individuals drawn at random from a parent population with a Laplacian distribution defined by equation (2) is given by

$$x_n^* = \frac{\log_e n}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

If the effective flaws (i.e. those correctly oriented to initiate fracture) are assumed to be distributed throughout the material with an average density ρ (i.e. ρ=number per unit volume), then the total number of effective flaws in a specimen of volume V is

$$n = \rho V$$

and thus

$$x_v^* = \frac{\log_e \rho V}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

It also follows from Griffith's theory that the strength S_v of a specimen of volume V is

$$S_v = \frac{k}{\sqrt{x_v^*}}$$

where k is a constant appropriate to the slenderness ratio in question.

Hence,

$$S_v = \frac{k}{\sqrt{\frac{\log_e \rho V}{\lambda}}} = \frac{k_1}{\sqrt{\log_e \rho V}} \quad . \quad . \quad . \quad (5)$$

where $k_1 = k\lambda^{\frac{1}{2}}$

Thus, if the assumed flaw size distribution is correct and if a large correctly oriented flaw at any point in the specimen can initiate fracture, equation (5) gives the required relation between strength and specimen size.

It is also shown in the Appendix that, in the absence of other sources of variation, the standard deviation of the strength should increase approximately as the cube of the mean strength as a result of random variation in the maximum flaw size. In practice there will naturally be other causes of variation so that this relation may not be observed. It is important to note, however, that there is a fundamental reason for expecting a large increase in the variability of results with decreasing specimen size which might otherwise be assigned to experimental error.

(*d*) *Observed Size Effect in Anhydrite of Constant Quality.*—In view of the foregoing, it was of interest to compare the size effect in two anhydrite samples with appreciably different crystal sizes, but each of constant quality. The very coarse 204 anhydrite and the finer 207 anhydrite were used for this purpose. It was desirable in these tests to cover a large range of strength; since strength changes increasingly rapidly with decreasing size, it was only practicable to do this by proceeding to the smallest possible sizes. Specimens with side lengths down to 0·15in were prepared from the 207 anhydrite, but the ready flaking off of cleavage fragments from the 204 anhydrite limited the minimum side length to 0·25in. Various other practical considerations necessitated testing the two samples at different slenderness ratios. The results obtained are given in Table II.

In the case of the 207 anhydrite the trend of mean strength with size is obvious. From the values of the mean strengths an average

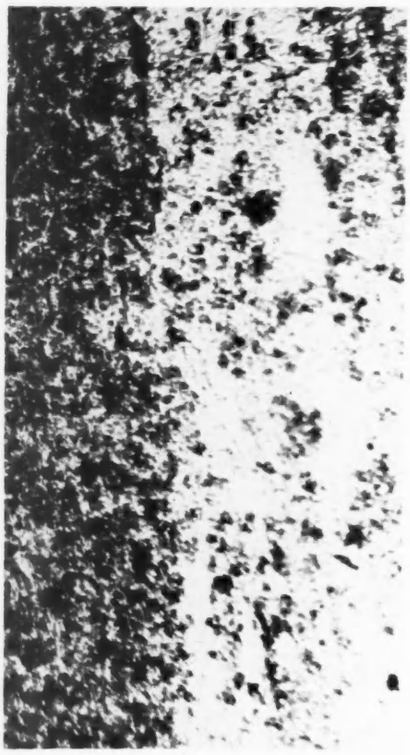

Fig. 7—Anhydrite 208. Impure stone from mine. Crystal size typical of much of mine anhydrite. ×140

value of $3{\cdot}5\times10^9$ per cubic inch can be calculated for ρ, i.e. this is the apparent number of effective flaws per cubic inch. Fig. 9 shows the mean strengths plotted against $(\log_{10}\rho V)^{-\frac{1}{2}}$, using this value of ρ. The points reasonably fit a straight line which,

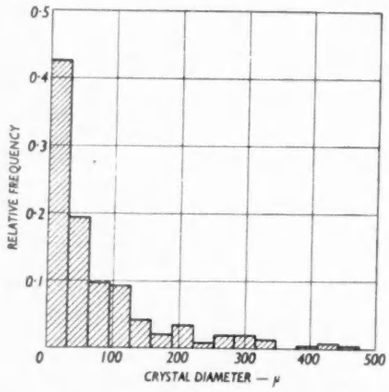

Fig. 8—Frequency histogram of crystal size for anhydrite 204

if extrapolated, passes through the origin indicating, in accordance with the above theory, that the strength of specimens of indefinitely great size will tend towards zero. It should be noted here that equation (5) above is insufficient to indicate whether the

TABLE II—*Size Effect in* 207 *and* 204 *Anhydrite*

Sample code No.	Specimen side length (inches)	Slenderness ratio	No. of specimens tested	Mean compressive strength (tons/ft²)	Range of observed strengths (tons/ft²)	Standard deviation (tons/ft²)
207	2	0·3	5	2260	2200–2330	56
	1	0·3	8	2470	2430–2510	36
	0·5	0·3	10	2900	2730–3090	128
	0·25	0·3	11	3180	2930–3410	169
	0·15	0·3	9	3430	3140–3970	240
204	1	0·6	4	840	770–950	81
	0·5	0·6	9	890	780–960	54
	0·25	0·6	8	960	860–1050	79

assumption that the number of flaws is proportional to specimen volume is correct. The data can be equally well represented by straight lines of the type in Fig. 9 by assuming that the number of flaws in a specimen is proportional to the square of its linear dimensions or directly to the linear dimensions if appropriate values of the constants are chosen. It is shown in the Appendix,

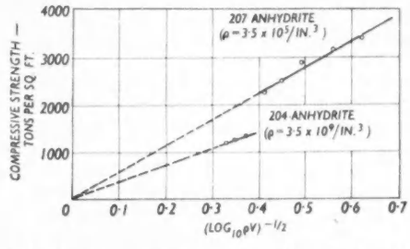

Fig. 9—Compressive strength : size relation for anhydrites 207 and 204. (Specimen slenderness ratio = 0·3)

however, that the logarithm of the number of effective flaws in a specimen can be estimated independently of their location in it from the ratio of the mean strength and the standard deviation due to random variations in flaw size. The figures from three smallest sizes of specimen, which are likely to give the best approximations, accord best with the assumption that $n \propto V$.

The estimated strengths of the 204 anhydrite specimens at a slenderness ratio of 0·3 are 1180, 1240 and 1320 tons per square foot for the 1in, 0·5in and 0·25in side lengths, respectively. Here the strength manifestly changes much more slowly with size than in the 207 anhydrite. This is due to two factors :

(1) The effective flaw density is higher by a factor of 10^4 in the 204 anhydrite.

(2) The value of the constant k_1 in equation (5) (slope of the lines in Fig. 9) is lower for anhydrite 204. This would be expected from the above theory since k_1 for a given slenderness ratio is mainly determined by the magnitude of Young's modulus, the specific surface energy and λ. Young's modulus and the specific surface energy are probably sensibly constant (no information is available for the specific surface energy, but the substantial constancy of the longitudinal wave velocity in anhydrite samples of different crystal size indicates that Young's modulus does not vary widely). The value of k_1 is therefore probably dependent chiefly on λ and should be smaller for coarse than finely crystalline material as observed above.

The adoption of the simple chain model and the assumption of a Laplacian distribution of flaw sizes thus gives a fair approximation of the strength-size relationships for these two samples of anhydrite.

Size Effect in Run-of-Mine Stone

The preceding sections have shown that the effect of size changes upon the strength of anhydrite are determined essentially by two variables which are the parameter λ defining the distribution of flaw (crystal) sizes and the density ρ (number per unit volume) of these flaws. When these two variables are constant, i.e. when the anhydrite quality is uniform, the strength-size relation can be predicted. The anhydrite in the mine is very variable in strength, however, so that the values of λ and ρ may vary widely from sample to sample. Equation (5) was, therefore, unsatisfactory for estimating the strength of pillars, each of which is composed of a variety of stone types, and an alternative method of representing the size effect was required which takes into account this variability.

Let it be assumed that the distribution of strengths for a certain small size of specimen is known and let this size be called the unit size for the slenderness ratio in question. Any larger specimen with the same slenderness ratio may now be regarded as being constructed of a number n of specimens of unit size. Now, according to the weakest link hypothesis, the strength of a specimen containing n units will be the strength of the weakest among these n individuals and the decrease in strength with increasing specimen size is the result of the increasing probability that a weaker unit will be present as the number of units increases. The formulation of the size effect thus again becomes a problem of the statistics of extreme values, but it is first necessary to know the form of the probability density function $f(x)$, which relates the strengths of the unit size to their frequency of occurrence. This is obviously a matter of fundamental importance, but there is, unfortunately, no practicable method of determining the strength distribution accurately. A form of $f(x)$ must therefore be assumed having the characteristics required by general considerations. The general form will be as follows.

Since negative strengths are impossible, $f(x)$ should be zero when x is zero. Similarly, since infinite strengths are impossible, $f(x)$ should, after passing through the mode, ideally become zero again at some finite value of x, which represents the strength of the unflawed material. As the distribution of the strengths of small specimens is not heavily skewed, $f(x)$ should also be fairly symmetrical about the mode. The simplest distribution best satisfying these requirements is that used by Weibull[14] in investigating the strength of materials which may be expressed as

$$f(x) = \alpha\beta x^{\beta-1} \cdot e^{-\alpha x^{\beta}}$$

where α and β are constants and $x \geqslant 0$, $\alpha > 0$, $\beta > 1$.

The assumption of this distribution leads to the following strength-size relation (see Appendix).

$$\log S = K - \frac{1}{\beta} \log V \quad . \quad . \quad . \quad (6)$$

where K is a constant and S and V are the specimen mean compressive strength and volume as before. The standard deviation of the strengths should be proportional to $V^{-2/\beta}$.

The normal (Gaussian) distribution is also satisfactory for the range of strengths and sizes usually amenable to investigation.[15] Although it has the defect of admitting negative strength values, its use will also be considered as it illustrates more clearly the statistical principles involved. This distribution gives the following approximate relation between strength and size :

$$S = \mu - \sigma(2 \log_e n)^{\frac{1}{2}} + \frac{\sigma(\log_e \log_e n + \log_e 4\pi)}{2(2 \log_e n)^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where μ and σ are respectively the mean strength and standard deviation for the unit size and n is the number of unit sizes in the specimen of mean strength S. The standard deviation of the strengths should be proportional to $(12 \log_e n)^{\frac{1}{2}}$ (see Appendix).

As most of the mine pillars have slenderness ratios near 0·5, this ratio was chosen for the investigation of the size effect in run-of-mine stone. Preliminary results indicated that, for a normal distribution, the unit size corresponded approximately to specimens with a side length of 1in. Specimens of this size were, therefore, prepared from a variety of types of stone representing, as far as possible, the range known to exist in the mine. Further specimens were prepared with side lengths of 2in, 4in and 10in, the intermediate sizes (2in and 4in) being chosen to give approximately equal spacing of the estimated mean strengths. The results obtained are summarised in Table III:

Table III—*Effect of Size on Strength of Run-of-Mine Stone*

(Slenderness ratio = 0·5 in all cases)

Specimen side length (in)	No. of specimens tested	Mean compressive strength (tons/ft²)	Range of observed strengths (tons/ft²)	Standard deviation (tons/ft²)
1	44	2090	1430–2770	296
2	29	1630	1300–1970	166
4	14	1560	1300–1790	132
10	4	1080	930–1290	172

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(To be concluded)

Hydro-Electric Progress in Canada, 1958.—A net total of 2,485,040 h.p. of new hydro-electric capacity was installed in Canada during 1958 (after making allowance for the dismantling of 6360 h.p. of existing capacity). The previous record year was 1954, during which 1,758,450 h.p. of new capacity was completed. Ontario's total of 1,301,800 h.p. of new capacity installed during 1958 was the highest among the provinces, followed by Quebec, which added 900,000 h.p. The total installed capacity of water power plants in Canada is now listed at 22,376,048 h.p. In addition to installations completed in 1958, new developments or additions to existing plants at present under construction are expected to add about 2,000,000 h.p. of new capacity during 1959. The building of new thermal-electric plants or additions to existing plants was increasing in some areas of the country ; the construction of main transmission lines, distribution lines and substation capacity also proceeded vigorously during the year. This information is given in the annual review of Canadian water power, *Hydro-Electric Progress in Canada*, 1958, copies of which may be obtained free of charge from the Director, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.

Fuel Problems in Merchant Ships.—On January 14 a paper entitled "Fuel Problems in Merchant Ships" was presented by W. McClimont, B.Sc., to the Institute of Fuel. The paper gives the four main categories of ship propulsion units and points out that to-day marine propulsion systems can only be competitive if they can use residual fuel, marketed as Bunker C grade. The nature of this fuel is examined and reference made to the increases, in recent years, in the vanadium and sulphur content and also to the control of the water content to control the amount of sodium present. Shipboard storage and its influence on the fuel is discussed, particularly sludge formation, and the three main problems encountered in boilers are considered. Damage to brickwork is thought to be more a matter of spalling than of slag erosion, and it is suggested that the significance of vanadium may have been overrated in the problem of bonded ash deposits in conventional marine boilers. Experience on the problems of deposits and corrosion in superheaters is reviewed, and the detrimental effect on boiler efficiency arising from air heater corrosion and blocking is emphasised. Cylinder wear and sticking piston rings are mentioned among the problems encountered in diesel engines when burning residual fuels, the troubles arising in gas turbines through a similar cause being ash fouling and corrosion.

LETTERS AND LITERATURE

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

IMPLEMENTATION OF STANDARDS

SIR,—"Standardisation of Grinding Wheels," on page 112 of THE ENGINEER of January 16, 1959, illustrates a big problem. The particular case is that makers of grinding machines have made little effort to design their machines so as to use the standard wheels provided by B.S. 620, and machine users have not used their purchasing power to induce manufacturers to do so. B.S. 1440 of 1948 provides a similar illustration with regard to standard lengths of V-belts and there are others.

Several ways have been suggested for getting British Standards implemented. In the U.S.S.R. failure to observe state engineering standards is punishable at law but any suggestion that B.S.I. should be given dictatorial power gains little support. Another proposal is that in B.S.I. Technical Committees the manufacturers should undertake to produce the standardised equipment by a given date and the users should undertake then to buy it, but for complex reasons neither side can give such undertakings: the reasons put forward stem from manufacturers wanting to be assured that they will recover their redesigning and retooling costs while the users cannot honestly give such assurances. A frequent suggestion is that groups of users should combine to purchase only from the manufacturer or manufacturers who produce to the B.S. but this is again impracticable because the price of the standardised equipment will, at first, often be higher than individual users are already paying for equipment which serves their purposes. Moreover, such agreements would now infringe the Restrictive Trade Practices Act.

The same problem arises within any large manufacturing organisation. Should the documents issued by the Standards Department be mandatory or should it be left to individual works engineers to change over to standards as and when they think fit? One very large organisation includes in some of its standards the words "Departure from this Standard is not permitted without reference to the Director of Standardisation." Presumably the Director heads a large Standards Department, and even so, transgressions may occur: for instance, soldiers are not permitted to apply anything but standard dubbin to their boots, but they use polish.

In the organisation in which I work compliance with standards by works engineers is voluntary and the method works well because works engineers are rational people and in time good standards establish themselves by their merits. But this procedure involves some organisational untidiness, particularly when standardisation is combined with a system whereby every bit of material in every works stores has to be given a multi-digit code number.

To make standards both mandatory and beneficial requires a Standards Department of considerable size. For one thing, whenever a new standard is produced relevant practices throughout all the works must be reviewed with a view to declaring what materials are obsolete or obsolescent and amending the stores catalogue. For another, bits of non-standard equipment will inevitably keep coming into the works and at some stage these must be screened to see which should become standard, which rejected and which should remain in use without being standardised. If a Standards Department undertakes such tasks, Parkinson's Law comes into operation, also a damper is put on the initiative of men in the works: e.g. proposals coming from the works' "suggestions" boxes cannot be tried out without prior approval of the Director of Standardisation.

It may help to consider the problem in a wider context. The Ten Commandments were a mandatory set of standards but the historical books of the Old Testament show that they were never for long effectively implemented. Moses himself had to be penalised by Higher Authority for a degree of non-compliance. When the Ten were later reduced in number it was left entirely to every individual to decide to what extent he would comply with the two essential standards, and useful success was achieved. In Victorian times some heads of families tried to make the Commandments mandatory with the result that the next generation denigrated them in *Eminent Victorians*, *The Barretts of Wimpole Street*, and many lesser works. Working to standards in engineering comes within the wide bounds of moral behaviour and it would seem better to proceed by persuasion and in the belief that the standards will establish themselves by their merits rather than by being dictatorial.

O. R. TUCKER

Braunston,
February 3, 1959.

Book Reviews

Pratique de la mesure et du contrôle dans l'industrie, tome I—**pressions, niveaux, débits.** By J. BURTON. Dunod-Editeur, 92, Rue Bonaparte, Paris (6ème). Price 4400 francs.

IN this work the author (chef thermicien, S.A.M. d'Espérance—Langdoz, Liége) sets out to describe the manner in which pressure, vacuum, fluid depth and flow rate are measured both in industry and in the engineering laboratory—with, in most cases, a bias towards the industrial type of measuring device. A feature of this book which is particularly pleasing is that industrial instruments are treated on a par with those more appropriate to the engineering laboratory. The reader infers—quite correctly—that industrial instruments are important in their own right: they have to be designed with care and skill equal to that applied to their laboratory counterparts, if they are to function satisfactorily under the adverse installation conditions usually associated with industrial instrumentation.

The text itself is clear, follows a strict logical sequence, and the work is quite devoid of extraneous matter. Also, very wisely, the author has resisted the temptation to deal with problems of automatic control. In this respect the title of the work is a little misleading. Unless it is eventually intended to add a section on automatic control—and this is not indicated in the prospectus for future volumes—the word "contrôle" as it appears in the title, should be taken as referring to the purposes for which industrial instruments are so often used—i.e. for quality control of a product being processed. Illustrations are numerous and for the most part are well drawn and fully captioned line diagrams: commendable restraint has been exercised in limiting the number of photographic reproductions.

Although extensive in its coverage, the book in no way resembles the "handbook" class of publication, each chapter being presented as a continuously developing text. The fact that advertising matter (relating to the instruments described) appears after the alphabetical index, is, for British readers, a matter of some interest; since the advertisements are sufficiently numerous to give this section of the book the characteristic of a trade directory. The main text itself is followed by some twenty-one curves and charts useful for computing purposes, these being accompanied by full instructions (with numerical examples) for using them. The book will appeal to both academic and industrial readers and it will be particularly welcomed as a teaching text.

Of particular interest, is the information which precedes the general text of each of the chapters since this gives, in tabular form, a classification of instrument types, together with ranges covered and the degree of precision with which measurements can be made within these ranges. Whilst with any encyclopedia work of this kind it is always possible to notice certain omissions, it is, in this case, interesting to notice the inclusion of a number of instruments which are not usually treated in British and American texts. Thus, for example, the author gives a fairly detailed study of the ring-balance differential manometer and its variants and of the "Askania" proportional flowmeter—the possibilities of which (latter) instrument have not, perhaps, been fully exploited in the United Kingdom. Generally speaking the work is up to date—it includes, for example, a description of an isotope technique for determining the position of a float used as a tank contents gauge, and of electromagnetic and ultrasonic flowmeters—but no emphasis is put on these methods and the extent of their mention is relatively brief.

Theoretical treatments are not uniformly distributed over the subject matter (in fact, this would be quite impracticable in a work dealing with so many different instruments) the author having introduced detailed theoretical treatments mainly in those cases where they are of interest to the instrument user. Thus the theory relating to the design of metering orifices—which can be manufactured by the user for use in conjunction with proprietary designs of recording and integrating differential manometers—is given in some detail: on the other hand, only brief mention is made of the theory relating to

the rotameter—just sufficient, in fact, to explain its method of operation.

From the point of view of the research worker and instrument designer in this field, more copious references to original literature would be very welcome. To be sure, the author gives a bibliography at the end of the book, but this is limited in extent and refers mainly to other works of reference rather than to individual papers. The omission of literature references in the text has obviously been done deliberately and has, in fact, resulted in a readable text which goes straight to the point with little or no digression. This is the correct approach (especially where teaching texts are concerned) but it is suggested that in future editions a few pages should be devoted, after each chapter, to present a list of papers which have been consulted in compiling the text. Whether or not such bibliographical references were referred precisely to corresponding mentions in the relevant section of the main text would be of little importance from the specialist readers' point of view.

Treatise on the Internal Mechanics of Ball, Tube and Rod Mills. By H. E. ROSE and R. M. E. SULLIVAN. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 25s.

THIS treatise deals mainly with the processes occurring during the fine grinding of materials in mills of the kind in which the moving casing contains a free mass of grinding media. Although in theory the casings of such mills may be tubes, cones or any other body generated by the rotation of a suitable geometrical figure about an axis, whilst the grinding bodies may be of any shape, in practice a very limited number of forms of mill shell are used whilst the grinding bodies are usually spherical balls or rods.

Restriction of the treatment to this kind of mill excludes consideration of mills using one, or only a few, balls, leads to simplification of the treatment since the behaviour of the charge is largely statistical. We are then shown that this statistical foundation lends itself to treatment to a remarkable extent by the methods of dimensional analysis.

On the basis of such treatment the authors have deduced, and partly evaluated numerically, the fundamental equations relating to the motion of the charge within the mill, the power required to drive the machine, the rate of grinding within the mill, surging of the mill charge and the rate of metal wear.

The difficult problem of the theory of comminution of solid bodies is tackled in Chapter 4. The many approaches by other international workers are considered and the basic difficulties encountered in the various researches are explained. The authors do not formulate a general law of comminution of their own and appear to doubt, as do we, the existence of such a general law. It is clearly wrong to lay undue emphasis upon any one " law " of comminution whilst the basic knowledge of the subject is in the present undeveloped state and the authors have wisely restricted themselves to emphasising the proven fact that coarse grinding approximates to Kick's law whilst fine grinding is more nearly in accord with the law of Rittinger.

The authors introduce, in Chapter 5, the outline of a theoretical treatment developed by one of them (Rose) in which a theoretical treatment for the internal dynamics of a ball mill, leading to expressions for rate of grinding and metal wear, are developed from considerations of the probability of a particle entering a " zone of operation " around the contact point between a pair of balls and of the history of the particle after it enters this zone.

This treatment appears to involve a gross over-simplification of the problem but, even so, it leads to the prediction of results which have been observed in practice, but which appear not to have been previously predicted theoretically.

The remaining chapters on metal wear in mills and on the role of additives in milling are framed on similar lines and, in common with the rest of the book, are adequately equipped with curves and data.

The book is neither a collection of formulæ for designers ; nor is it a textbook setting forth accepted theories—since there are none coherently covering the internal mechanics of ball mills. It is a comprehensive and technically correct development of formulæ by means of the systematic application of dimensional analysis ; the methods, furthermore, are convincing in their statements and lead to results in a form suitable for numerical and, if necessary, electronic computation.

It would appear that these formulæ could also be combined with others of the same structure dealing, for example, with the mixing of two powders, in order to introduce additional mill characteristics into a still more refined treatment.

This little book, which could well be read by all who have contact with milling problems, may be foreseen to forge the way to the general acceptance of the method of dimensional analysis as the basis of approach to the solution of the technical problems relating to powdered materials.

The Performance and Design of Alternating Current Machines. Third edition. By M. G. SAY. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 37s. 6d.

PROFESSOR SAY'S book on a.c. machines has long been known as an excellent book for undergraduate students. There are many books on this subject but this is as good as any in two important respects. On the theoretical side it fulfils very well the requirement that no statement should be made without a satisfactory explanation. On the practical side it provides a wealth of well-illustrated information of the kind needed to supplement a lecture course. Indeed, it is a useful reference book for an engineer long after he has finished his formal studies.

The new edition retains a good deal of the original material but there are substantial revisions both on the theoretical and practical side. Discussions of modern developments have been included, for example, surges in transformers and hydrogen cooling of turbo-alternators. M.K.S. units are used and the per unit system is introduced. Many explanations of theoretical points have been improved. The most interesting, and perhaps the most controversial, feature of the new edition is the presentation in an undergraduate text book of the concept of a " generalised electrical machine." An additional chapter and many inserted notes assert the possibility of a unified approach to the subject.

The theory of the generalised machine has been fully worked out in terms of advanced mathematics, but the problem of applying the concept to an elementary treatment has not yet been solved. The present book does no more than make a step in the right direction. The concept must permeate the treatment of steady operation and not just appear in a supplement at the end. The generalisation process reduces any machine to three essential quantities.

(1) A resultant current distribution along the air gap line, set up by constant or time-varying currents in discrete circuits.

(2) A resultant m.m.f. distribution along the air gap line determined by the current distribution.

(3) A resultant flux density distribution along the air gap line determined by the m.m.f. distribution.

The above quantities produce voltages and torque which are equated to the applied voltages and torque. The relationships between the conditions in the actual machine and the above essential quantities require careful explanation which can well be made for the simple condition of normal operation. Once the concept is grasped in relation to normal steady operation, the transition to transient conditions will be quite easy.

The requirements for a student's text book are very different now from what they were only ten years ago. It is more important than ever that the fundamental electromagnetic principles should be studied independently and thoroughly because of the increasing variety of such apparatus as relays, liquid pumps, and devices for atomic research. The rotating machine is only one example of the application of these principles, although it is still important enough to warrant considerable attention. Perhaps only forty lectures, or even fewer, can now be spared for machines and transformers during a three-year course in electrical engineering, but this will suffice if a satisfactory unified treatment can be found.

We would like to see a text book designed on the same general lines as Professor Say's book, half theory and half practice, but covering both d.c. and a.c. machines in a compass of 400 pages. Many of the variations could be omitted. An understanding of the essential principles would, in fact, be more easily achieved if they were presented without too many special transformer connections or too many variations of induction motor operation. In the meantime, the present book, together with its companion volume on d.c. machines, provides practically everything that a student needs on this subject. Any teacher must be grateful for such a thorough and well-compiled book to supplement his lectures.

Books Received

Northern Region Engineering Buyers Guide, 1958–59. The North-East Engineering Bureau, 18, Ridley Place, Newcastle upon Tyne, 1. Price 2s. 6d.

Landwirtschaftlicher Wasserbau. Third edition. By G. Schroeder. Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3, Germany. Price DM.54.

Metal Rectifier Engineering. By E. A. Richards, Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 37s. 6d.

Handbook of the Petroleum Industry. Edited by G. Sell and H. A. Dossett. George Newnes, Ltd., Tower House, Southampton Street, London, W.C.2. Price 25s.

Mathematics Applied to Electrical Engineering. Second edition. By A. G. Warren. Chapman and Hall, Ltd., 37, Essex Street, Strand, London, W.C.2. Price 70s.

Introduction to the Design of Servomechanisms. By J. L. Bower and P. M. Schultheiss. Chapman and Hall, Ltd., 37, Essex Street, Strand, London, W.C.2. Price 104s.

Handbook of Physics. Edited by E. U. Condon and H. Odishaw. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 194s.

Handbook of Automation, Computation and Control, Vol. 1. Edited by E. M. Grabbe, S. Ramo and D. E. Wooldridge. Chapman and Hall, Ltd., 37 Essex Street, Strand, London, W.C.2. Price 136s.

Electromagnetic Vibration Generators in Resonant Fatigue Testing

By T. M. DOWELL*

An analysis of the operation of electromagnetic vibration generators in resonant fatigue testing is presented. It provides the information required to decide upon the size of vibrator and the power requirements for any given fatigue testing programme, and indicates how maximum power may be transferred to the component under test.

ELECTROMAGNETIC vibration generators are being increasingly used for a variety of industrial processes and research purposes.[1, 2] They operate on the same principle as an ordinary radio loudspeaker; namely, that electrical energy fed into a coil suspended in a magnetic field is transformed into mechanical work. The mechanical properties of the system are seen at the vibrator input terminals as electrical quantities and the entire mechanical and electrical system is capable of being represented by an equivalent electrical network.

The fundamental equation relating force output to current input is:

$$F \propto BIl.$$

While users of these vibrators will usually wish to know the thrust output in units of pound force the analysis is greatly simplified by use of the internationally agreed M.K.S. system of units. Here,

$$F = BIl$$

where

F = Force in Newtons (1 lb force = 4·45 Newtons).

B = Flux density in Webers per square metre.

I = Current in amperes.

l = Length in metres of conductor cutting field flux (1ft = 0·3048m).

Since, for a given vibrator, the flux density and conductor length are fixed, the vibrator performance is usually quoted in pound per ampere. From a knowledge of the vibrator impedance and current, it is common practice to relate the force output to the power input. This information is usually contained in the vibrator specification, e.g. 500 lb thrust for 1kW input.

The above information on the vibrator performance is sufficient for a large number of applications, but one very important exception is in the field of resonant fatigue testing. Indeed, in this particular field the information relating vibrator thrust and power can be very misleading to the unwary. In order to assess the power requirements for such tests, it is necessary to analyse more fully the operation of electromagnetic vibration generators to ascertain how the input power is divided between losses in the vibrator and work done on the resonant system. As already stated, the principle of operation is that current flowing in a coil suspended in a magnetic field produces a force which induces motion in the coil. The motion of the coil, in the magnetic field produces, in the coil, a back electromotive force which opposes the motion. Thus a voltage applied to the moving coil has to supply the voltage drop in the coil and overcome the back electromotive force.[3]

Hence:

$$E = IZ_B + e \quad . \quad . \quad . \quad . \quad (2)$$

where

E = Voltage applied to moving coil.

I = Current in moving coil.

Z_B = The "blocked" impedance of the moving coil, i.e. is measured with the coil rigidly clamped and represents coil losses.

Therefore

$$\frac{E}{I} = Z_B + \frac{e}{I}$$

or

$$Z_T = Z_B + Z_M \quad . \quad . \quad . \quad . \quad (3)$$

where

Z_T = Total impedance across moving coil terminals and $Z_M = \frac{e}{I}$ . . (4)

The back electromotive force, e, is given by:

$$e = Blv \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where v = velocity of moving coil.

Substituting (1) and (5) into (4) gives:

$$Z_M = \frac{e}{I} = B^2 l^2 \frac{v}{F} \quad . \quad . \quad . \quad . \quad (6)$$

When, as in resonant fatigue testing, the motion is harmonic, displacement $x = x_0 \sin \omega t$, and

$$v = \omega x_0 \sin\left(\omega t + \frac{\pi}{2}\right).$$

Also

$$F = F_0 \sin(\omega t + \phi),$$

where

ϕ = phase angle between force and displacement = $\frac{\pi}{2}$ at resonance.

Therefore, at resonance,

$$Z_M = \frac{e}{I} = 2\pi B^2 l^2 f \frac{x_0}{F_0}.$$

For a given vibrator $2\pi B^2 l^2$ is a constant, therefore

$$Z_M = Kf\frac{x_0}{F_0} \quad . \quad . \quad . \quad . \quad (7)$$

Thus Z_M is a function of the mechanical characteristics of the system and is in fact the "mechanical impedance" as seen by the vibrator. At a mechanical resonance Z_M is large since a large displacement, x, is obtained for a small thrust, F. The ratio x/F is a function of the amplification factor, Q, of the mechanical system. The total impedance across the moving coil terminals is composed therefore of the blocked impedance and the mechanical impedance which, for the purpose of resonant fatigue testing, is a function of the resonant frequency and amplification factor.

Fig. 1 shows the impedance/frequency characteristics of a vibrator exciting in plane bending a rolling-stock wheel and axle assembly of resonant frequency 87·8 c/s and amplification factor 150. Quite apart from the question of the division of power in the vibrator, this impedance rise has important consequences as a result of the well-known "Maximum Power Transfer Theorem." Since, for maximum power transfer, the impedance of the source and load must be "matched," it is desirable to employ

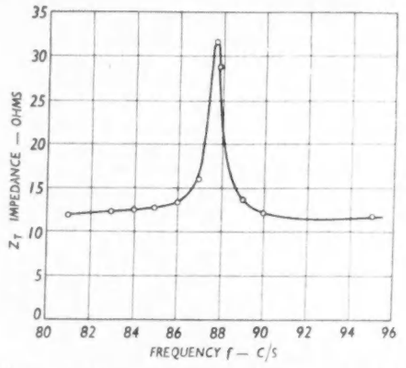


Fig. 1—Impedance rise of vibrator at mechanical resonance (Q=150)

a multi-ratio output transformer with the electronic-power amplifier driving the vibrator.

Since the vibrator impedance at resonance is a function of the resonant frequency and amplification factor of the mechanical system, impedance measurements can be used to study the behaviour of the mechanical system. It is possible, for example, to study crack propagation in the test specimen since this will result in a progressive decrease in the amplification factor. In non-resonant tests, or tests at low amplification factor where Z_M is only a small proportion of the total impedance, the method will not, however, be suitable.

Power Requirements.—The distribution of input power to the vibrator follows immediately from the electromotive force equation (2):

$$EI = I^2 Z_B + eI$$

$$e = Blv$$

$$I = \frac{F}{Bl}.$$

Therefore

$$eI = Fv.$$

Therefore

$$EI = I^2 Z_B + Fv \quad . \quad . \quad . \quad . \quad (8)$$

At resonance e and I are in phase, since the force and velocity are in phase. Since, in the electrical equation, it is r.m.s. values of E, I and e which are used for power calculations, then it follows that F and v are also r.m.s. values in the above equation. The first term on the right-hand side of the equation is, of course, the losses within the vibrator (if Z_B is complex then the real part represents the loss component). The second term on the right-hand side is the expression for mechanical power. For a harmonically varying force acting upon a harmonic velocity of the same frequency:

$$Fv = \frac{F_0}{\sqrt{2}} \cdot \frac{v_0}{\sqrt{2}} = \frac{F_0}{\sqrt{2}} \cdot \frac{2\pi f x_0}{\sqrt{2}} = \pi F_0 x_0 f.$$

On assessing the power requirements for a fatigue test, it is therefore necessary to estimate the power going to mechanical work and to add to this the power dissipated in vibrator losses.

It is of considerable interest to investigate the division of power between vibrator losses and mechanical work on the basis of a constant voltage applied to the vibrator.

* Mechanical Engineering Research Laboratory, East Kilbride.

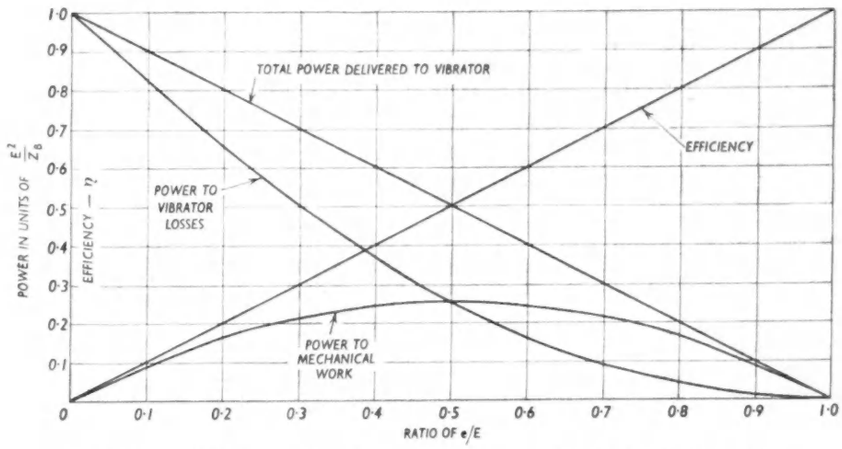


Fig. 2—Power distribution and vibrator efficiency against e/E for constant applied voltage E

From the above equations

$$Fv = eI = EI - I^2Z_B$$

Therefore

$$\frac{\partial(eI)}{\partial I} = E - 2IZ_B.$$

For a maximum value of eI, $I = E/2Z_B$. Therefore, from Ohm's law :

$$Z_T = 2Z_B$$

and from equation (3),

$$Z_M = Z_B.$$

The power to mechanical work as a function of the back electromotive force e for a constant applied voltage is also simply obtained :

$$eI = EI - I^2Z_B,$$

but

$$I = \frac{E-e}{Z_B}.$$

Therefore,

$$eI = \frac{Ee - e^2}{Z_B}$$

and

$$\frac{\partial(eI)}{\partial e} = \frac{E-2e}{Z_B}.$$

Therefore, for a maximum value of eI and therefore of Fv, the back electromotive force e is equal to half the applied voltage :

$$e = \frac{E}{2} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

This condition is satisfied when the mechanical impedance Z_M is equal to the blocked impedance Z_B. Fig. 2 shows the variation of the total power delivered, the division of the power to vibrator losses and mechanical work, and the vibrator power efficiency for values of e/E from zero to unity for constant applied voltage E to the vibrator.

The above analysis is true irrespective of the vibratory mode being excited by the vibrator, but the most appropriate method of satisfying the conditions for maximum power to mechanical work will depend upon the mode being excited. For bending tests variations in e are brought about quite simply by variations in the length r of the bending moment arm

$$e = Blv = Bl\omega r\theta$$

where $r\theta = x$ = distance moved by point of application of bending force.

The variation of bending moment M, with bending moment arm, r, for a constant voltage applied to the vibrator is also simply obtained.

Bending moment

$$M = Fr$$
$$= BIlr$$
$$= \frac{Bl}{Z_B}[Er - Bl\omega r^2\theta].$$

Therefore

$$\frac{\partial M}{\partial r} = \frac{Bl}{Z_B}[E - 2Bl\omega r\theta]$$
$$= \frac{Bl}{Z_B}[E - 2e].$$

The maximum bending moment is therefore obtained when the value of r is chosen such that the back electromotive force is half the applied voltage, i.e. when

$$r = \frac{E}{2Bl\omega\theta}$$

or

$$r\theta = x = \frac{E}{2Bl\omega} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The same result, $E = 2e$, is obtained if the expression for the bending moment M is differentiated with respect to the flux density B. Thus the condition for maximum power to mechanical work may be obtained by variation of the bending moment arm or of the flux density. This latter condition is, of course, only possible in the case of an energised field, but is particularly convenient in cases where e is greater than $E/2$. The desired equality can then be achieved by reducing the field energising current.

These results are a particular example of the " Maximum Power Transfer Theorem." While it is well known that for maximum power transfer from electronic amplifier to vibration generator these units must be matched to each other by means of an impedance matching transformer, it may not be so generally appreciated that this also applies to the transfer of power within the vibrator. from the electrical to the mechanical system, It should be noted, however, that the analysis is based on conditions of constant applied voltage. The situation is quite different when considering conditions of constant power applied to the vibrator. Under such conditions,

$$EI = \text{constant} = I^2Z_B + eI$$
$$= \frac{(E-e)^2}{Z_B} + eI.$$

Therefore

For eI to be a maximum, $E = e$ . . (11)

Fig. 3 shows the power distribution to losses and mechanical work, together with variations in applied voltage and vibrator current, for various values of e/E from zero to unity. This shows that power to mechanical work and power efficiency increase linearly with the ratio e/E. It should be noted, however, that the value of the applied voltage E rises very sharply after $e/E = 0{\cdot}8$ and that operation beyond this point would lead to insulation difficulties in the design of the moving coil. At this point, $e/E = 0{\cdot}8$, the theoretical efficiency is 80 per cent. This is a big improvement on the previously considered case of constant applied voltage E, where, under conditions of maximum power transfer to mechanical work, the efficiency was only 50 per cent. It should, however, be noted from Fig. 3 that as e tends to E it is at the same time tending to infinity. Since $e = Blv$, then e can be increased by increasing B, l or v. For a given vibrator, l is fixed and even if the magnet system has an energised field very little increase in B will be possible as the wire gauge of the field winding will have been chosen from the design value of energising current. This leaves the possibility of increasing v. As the velocity of the drive system is increased the mechanical losses, which are velocity dependent, will also increase. This will result in more power going to mechanical work in the form of mechanical losses in the drive instead of to work done on the component under test. In order to achieve maximum power to the test piece a compromise is necessary between increasing the percentage of electrical power being transformed to mechanical work and the resultant increase in losses in the drive system as e tends to E. This will result in an

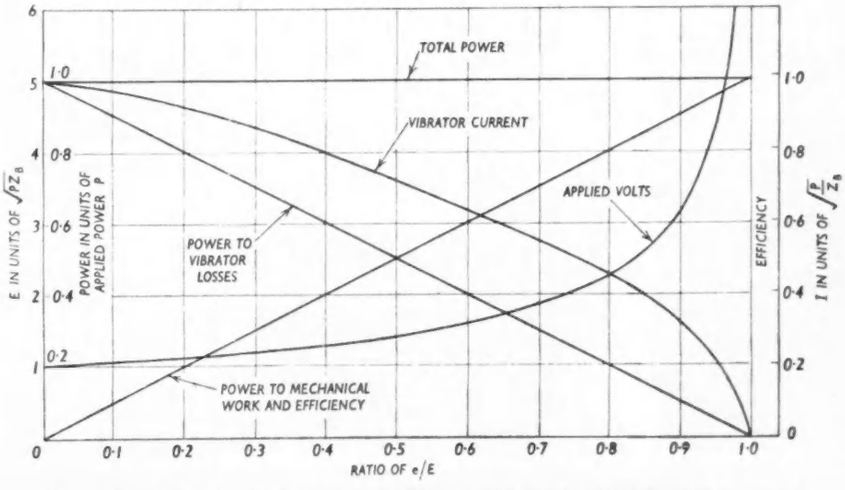


Fig. 3—Vibrator power, voltage, current and efficiency against e/E for constant applied power P

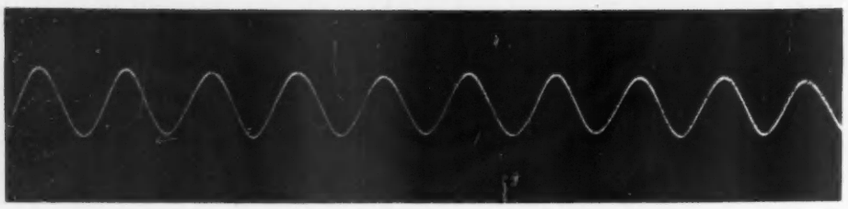


Fig. 4—Damped vibrations of wheel and axle assembly

optimum value of drive velocity and, therefore, an optimum value of bending moment arm if the component under test is being excited in bending.

Practical Application

The above considerations were applied to fatigue tests on rolling stock wheel and axle assemblies in which each assembly was resonated as a free-free beam by means of an electromagnetic vibration generator. In order to assess the thrust and power requirements for the tests, it was first necessary to know the amplification factor, Q, of the assembly comprising wheels, axle, moving coil and connecting-rod. To ascertain this it was decided to make a preliminary test using a small available vibrator of 25 lb peak thrust driven from an audio-frequency oscillator and amplifier of 30W output. Electrical resistance strain gauges were affixed at the position of maximum nominal stress, and strains measured by means of the laboratory dynamic strain-measuring bridge.[4] In order to assess the driving force, use was made of the manufacturer's "force factor" in pounds/amperes. For this driving force the stress at resonance was measured and the stress for the static application of the force calculated. From these figures amplification factor

$$= \frac{\text{stress at resonance}}{\text{stress for statically applied load}}$$

was found to be 170.

As an independent check on this value, the amplification factor was calculated from the logarithmic decrement of damped vibration at the resonant frequency. With the assembly being driven at its fundamental resonant frequency, the driving force was switched off and the damped vibrations recorded by means of an oscilloscope camera. Part of this record is shown in Fig. 4. The damping of the overall system is composed of :

(i) Coulomb damping (dry friction at the supports).

(ii) Hysteresis damping (internal friction in the axle).

(iii) Air damping.

(iv) Magnetic damping (in the vibrator).

The analysis of such a system is extremely difficult even when an exact expression for the damping function is known. However, it is well known that when the overall damping is light and the motion sinusoidal the results approximate closely to those obtained by assuming equivalent viscous friction.[5] With this assumption an examination of the trace of Fig. 4 gave the amplification factor as 150 (see Appendix). From this the thrust for the required stress was calculated. The power to mechanical work was obtained from the thrust, deflection of the point of application of thrust and resonant frequency.

Power to mechanical work $= \pi f F_0 x_0 \sin \phi$, where

ϕ = phase angle between thrust and displacement = 90 deg. at resonance.

The driving amplifiers were then chosen to have an output power of twice the power to mechanical work.

Experience on Bending Fatigue Tests.—Having selected vibrators and driving equipment of the requisite capacity, it was of considerable interest to compare their performance with that predicted by theory. Figs. 5 and 6 show the test rig for resonant fatigue tests on rolling stock axles. The impedance rise at resonance was very sharp (Fig. 1), and matching was performed by means of a continuously variable auto-transformer. The stresses for various values of bending moment arm under conditions of constant applied voltage E and input power P were obtained by experiment and are shown in Fig. 7. The graphs show that an optimum position exists for both conditions previously considered, constant applied volts and power.

Measurements of resonant frequency and total impedance Z_T were also made in the course of this experiment.

As previously shown :

$$Z_T = Z_B + Kf\frac{x}{F}.$$

The equations for a simple lever show that

$$\frac{x_1}{F_1} = \left(\frac{r_1}{r_2}\right)^2 \frac{x_2}{F_2}$$

where x and F are the displacement and thrust at length r along the lever. The graph of vibrator impedance Z_T against bending

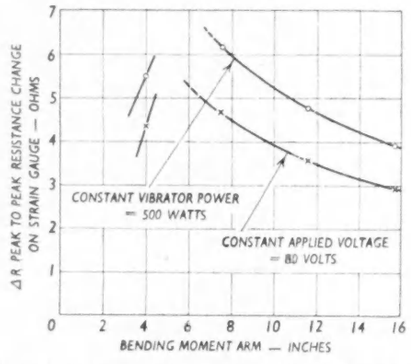
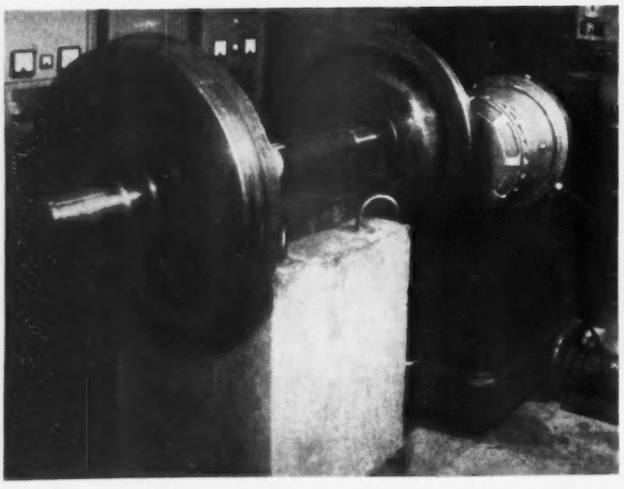
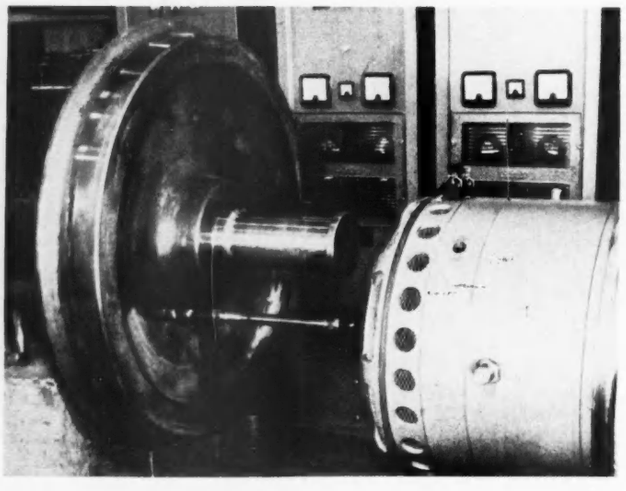


Fig. 7—Axle stress for various values of bending moment arm

moment arm r for constant frequency and amplification factor is therefore a parabola displaced from the origin by Z_B. This is shown in Fig. 8, together with the actual measured impedance. The departure of the measured impedance from the predicted is due to either a drop in resonant frequency or in amplification factor. The drop in resonant frequency shown in Fig. 8 is insufficient to account for the large discrepancy in the two impedance curves, which must therefore be due to a large drop in the amplification factor. Indeed, the drop in the resonant frequency is a clear indication that the losses in the system are increasing. To confirm this, strain measurements were made on the axle for various values of bending moment arm with constant input current, and therefore constant known thrust, and the amplification factor calculated. The results of this are also shown on Fig. 8 for various values of bending moment arm. This shows that very considerable losses were being introduced





Figs. 5 and 6—Test rig for resonant fatigue test on wheel and axle assembly

into the system as the displacement of the drive was increased.

These increasing losses, in the drive system, include not only those within the vibrator, but also losses in the connecting-rod. The vibrator coil suspension is deliberately made stiff in a radial direction in order to damp

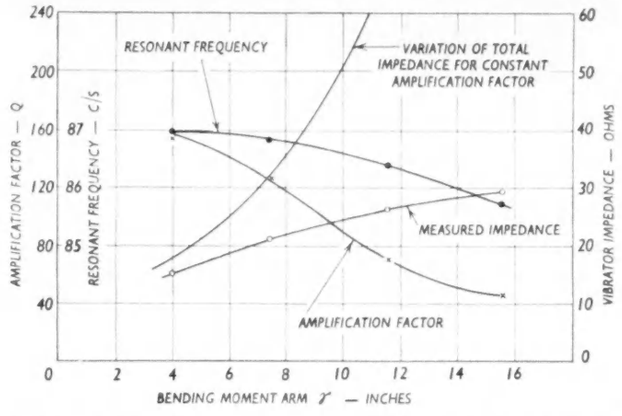


Fig. 8—Amplification factor, resonant frequency and vibrator impedance against bending moment arm

out any non-axial motion which may damage the moving coil. Since the point of application of the thrust to the wagon wheel describes an arc which increases with bending moment arm, the non-axial motion is taken up in the connecting-rod (Fig. 9), which was designed to be flexible to side thrusts and stiff to axial thrusts. There still exists, however, a fair amount of resistance to non-axial movements

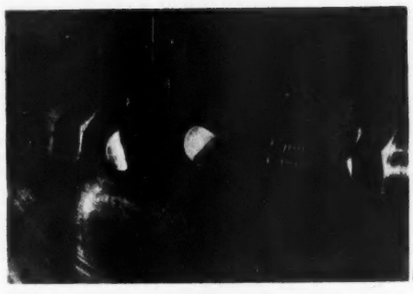


Fig. 9—Connection of vibrator to wheel and axle assembly

which contributes to the overall velocity sensitive losses in the drive.

The shape of the curve of axle stress for constant power input (Fig. 7) is then due to the fact that, as the bending moment arm increases and more power goes to the mechanical system, the amplification factor simultaneously decreases due to increased losses ; this results in an optimum position for driving the wheel and axle assembly.

Thus, when driving this wheel and axle assembly with the bending moment arm r equal to 7·5in, the vibrator impedance Z_T is 21 ohms. The value of Z_B was found, by measurement, to be 10 ohms. Under these circumstances :

Vibrator power efficiency

$$=\frac{Z_M}{Z_T}=\frac{Z_T-Z_B}{Z_T}$$

$$=1-\frac{Z_B}{Z_T}\simeq 50 \text{ per cent.}$$

The curve of measured impedance on Fig. 8 enables the efficiency, for any value of bending moment arm, to be calculated. It should be particularly noted that the power efficiency increases with the value of the bending moment arm not because the axle strain is increasing but because more power is going to the mechanical system in the form of losses in the drive.

Where it is possible to apply the exciting force to a resonant system at a nodal point, the vibrator efficiency, as defined above, may be very low but due to the small mechanical losses in the drive the resulting stress on the test piece may be high. For example, bending tests have been performed by applying torsional vibrations at one of the nodes of a bar vibrating in its first free-free mode.[6]

Direct Stress Fatigue Tests.—Since equations (1) to (9) and equation (11) are valid irrespective of the vibratory mode being excited by the vibrator they may be directly applied to direct stress resonant fatigue tests. Thus, for conditions of constant applied voltage, eI and therefore Fv is a maximum when :

$$e=\frac{E}{2}$$

i.e. when

$$Blc=\frac{E}{2}.$$

This equality can be achieved by varying B, in the case of an energised field, particularly when it is a reduction in the field flux that is required. Alternatively, for pure harmonic motion encountered at resonance the velocity is given by :

$$v=2\pi f x_0 \sin\left(\omega t+\frac{\pi}{2}\right)$$

and the desired equality can be obtained by designing the test piece or coupling to give the required displacement, x_0, and resonant frequency, f.

Conclusions

The vibrator theory indicates that, in order to be suitable for general-purpose resonant fatigue testing, it is essential that a multi-ratio output transformer be used with the vibrator driving amplifier if the available power is to be fully utilised. It is not sufficient to match the driving amplifier to the unloaded vibrator impedance no matter how flat the unloaded impedance/frequency graph may be. The actual impedance at resonance depends on the vibrator-blocked impedance, the resonant frequency of the mechanical system, and the ratio of moving coil displacement and thrust which in turn is a function of the amplification factor of the system.

For resonant fatigue tests in plane bending, care is required in selecting the value of the bending moment arm as this will have an important bearing on the stress obtained for a given power input and on the vibrator efficiency.

Since, at resonance, the total vibrator impedance is a function of the mechanical constants of the system, the vibrator impedance may be monitored in order to ascertain the condition of the test specimen. It is possible to observe the propagation of a fatigue crack since this results in a progressive drop in the amplification factor and a consequent decrease in vibrator impedance. This characteristic was utilised to automatically stop the fatigue tests described once a crack had formed.

Acknowledgments

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The work described has been carried out as part of the research programme of the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research. The article is published by permission of the Director of Mechanical Engineering Research.

APPENDIX :

Calculation of Amplification Factor Q from an Examination of Damped Vibrations at the Resonant Frequency

Fig. 4 shows the damped vibrations of a wheel and axle assembly when supported near the nodes on anti-vibration mountings. Since the damping is light and the motion nearly sinusoidal, it may be analysed by assuming " Equivalent Viscous Friction."

The equation of motion is then :

$$M\ddot{x}+R\dot{x}+Kx=0,$$

where

M=mass of system.
R=frictional coefficient.
K=stiffness of system.

The solution, for the oscillatory case, is :

$$x=Ae^{-\Delta t}\cos(mt+\phi)$$

where A and ϕ are constant, and

$$\Delta=\frac{R}{2M}$$

$$m^2=n^2-\Delta^2,$$

where n=undamped natural frequency

$$=\sqrt{\frac{K}{M}} \text{ rad/sec.}$$

The ratio of peaks one cycle apart=A_0/A_1 and at the peaks :

$$\cos(mt+\phi)=1.$$

Therefore

$$\frac{A_0}{A_1}=\frac{Ae^{-\Delta t_0}}{Ae^{-\Delta t_1}}=\frac{e^{-\Delta t_0}}{e^{-\Delta\left(t_0+\frac{2\pi}{m}\right)}}=e^{\Delta\frac{2\pi}{m}}.$$

In general, for peaks q cycles apart :

$$\frac{A_0}{A_q}=e^{\Delta q\frac{2\pi}{m}}.$$

Therefore

$$\log_e\frac{A_0}{A_q}=\frac{2\pi}{m}\cdot\Delta_q.$$

Measurement of successive film lengths by means of a vernier measuring instrument gave :

$$\frac{A_0}{A_{10}}=1\cdot 23.$$

Therefore

$$\frac{\Delta}{m}=0\cdot 0033.$$

Amplification factor

$$Q=\frac{\text{actual amplitude at frequency } \omega}{\text{amplitude at zero frequency}}$$

for same value of applied force F.

$$M\ddot{x}+R\dot{x}+Kx=F_0\cos\omega t$$

$$\frac{d}{dt}=i\omega, \text{ where } i^2=-1.$$

Therefore

$$[M(i\omega)^2+Ri\omega+K]x=F_0\cos\omega t=F_0e^{i\omega t}.$$

Therefore

$$x=\frac{F_0e^{i\omega t}}{(K-\omega^2M)+i\omega R}$$

and

$$|x|=x_0=\frac{F_0}{\sqrt{(K-\omega^2M)^2+\omega^2R^2}}$$

$$Q=\frac{x_0}{\delta_0}$$

where

$$\delta_0=\text{static deflection}=\frac{F_0}{K}.$$

Therefore

$$Q=\frac{F_0}{\sqrt{(K-\omega^2M)^2+\omega^2R^2}}\cdot\frac{K}{F_0}$$

$$=\frac{K/M}{\sqrt{\left(\frac{K}{M}-\omega^2\right)^2+\omega^2\left(\frac{R}{M}\right)^2}}$$

$$=\frac{n^2}{\sqrt{(n^2-\omega^2)^2+\omega^2 4\Delta^2}}.$$

At resonance (i.e. frequency for maximum displacement) :

$$\omega^2=n^2-2\Delta^2$$

and since Δ is very small Δ^2 may be neglected therefore

$$\text{at resonance } \omega\simeq n$$

and

$$Q=\frac{n}{2\Delta}.$$

Solving $m^2=n^2-\Delta^2$ and $\Delta/m=0{\cdot}0033$ gives the amplification factor. Since m and n are nearly identical for low damping, then :

$$Q\simeq\frac{1}{2}\frac{m}{\Delta}\simeq 150.$$

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EXOTHERMIC GAS GENERATOR.—A compact protective atmosphere generator developed by Royce Electric Furnaces, Ltd., of Walton-on-Thames, has a rated output of 150 cubic feet of prepared atmosphere per hour. This plant occupies a floor area of less than 3ft square, and larger units with capacities ranging up to 2000 cubic feet per hour are also available. In these units the prepared atmosphere is obtained by the controlled combustion of town's gas in a chamber lined with high-quality refractory and having refractory baffles to give the requisite temperature and turbulent flow. To conserve heat and give temperate working conditions, the lining is backed by a wall of thermal insulating bricks, the whole being enclosed within a gas-tight casing. From the combustion chamber the burnt gas passes through a water-cooled collection duct to a heat exchanger which effectively cools the gas, and removes the excess water vapour. The gases are finally purified in a vertical desulphurising retort containing iron oxide. It is stated that these generators are economical to run and are very suitable for supplying atmosphere to continuous furnaces used for the bright annealing of low carbon steels and copper brazing of mild steel components, for which it is essential that a protective atmosphere of known and controlled composition is used.

Two Sets of General Purpose Diesel Engines

Two sets of diesels of new design have been developed by Davey Paxman and Co., Ltd., to produce higher power within the same overall dimensions as existing units. One set consists of six-, eight- and twelve-cylinder air-cooled engines having a power range of 160 to 466 b.h.p., and the second group includes twelve- and sixteen-cylinder V engines which are pressure-charged or pressure-charged and intercooled, and range in output from 1100 to 1870 b.h.p.

THE need to produce engines of higher power without increase in weight and overall size in order to meet the strong competition of manufacturers abroad prompted Davey Paxman and Co., Ltd., of Colchester, to design and develop two new ranges of diesel engines. One set consists of mark Y.G.A., air-cooled units having a horsepower range of from 160 to 466 b.h.p., while the second set consists of mark Y.J.X. pressure-charged and mark Y.J.C. pressure-charged and intercooled, water-cooled engines with powers ranging from 1100 to 1870 b.h.p. Both sets of engines are additional to the existing marks of engines presently built by the company and have been developed to achieve the same degree of reliability already attained by existing designs. Although completely new in concept many parts of the engines, which we had the opportunity to inspect on a recent visit to Colchester, are based on well proven practice, while new items introduced as the result of a careful study of techniques in several spheres of engineering fields have been proved by intensive component rig tests. Such tests have served to eradicate the teething troubles usually met at the prototype stage and, to establish service reliability, it is planned to test the engines under the wide variety of operational conditions to be encountered at home and abroad.

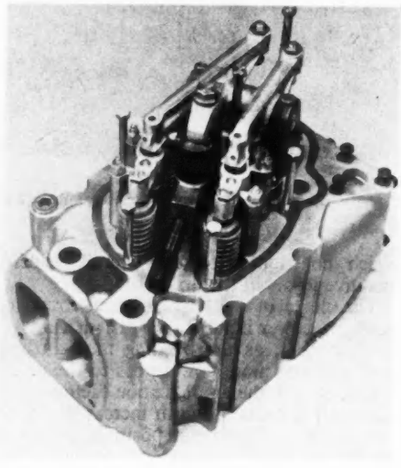
"VEGA" AIR-COOLED ENGINES

The increasing use of air cooling prompted the company to investigate its application to higher powered units and this has led to the introduction of the mark Y.G.A. engine range which consists of a six-cylinder in line engine and eight- and twelve-cylinder 90 deg. V form engines. These engines are suitable as power units for various oil well and oil field applications, also for road vehicles, railway traction, small craft and marine auxiliaries. All have a bore of 6in by 6·6in stroke and a compression ratio of 15 to 1, while the ratings are given in the accompanying table.

Engine	R.p.m.	Continuous rating	Automotive rating	Intermittent rating
12 Y.G.A.	2100	—	466	—
	2000	—	—	444
	1800	400	—	—
	1500	333	—	—
8 Y.G.A.	2100	—	310	—
	2000	—	—	295
	1800	265	—	—
	1500	222	—	—
6 Y.G.A.	2100	—	233	—
	2000	—	—	222
	1800	200	—	—
	1500	160	—	—

Maximum torque occurs at about 1350 r.p.m. and is : 1350 lb per foot for the 12 Y.G.A. ; 900 lb per foot for the 8 Y.G.A.; and 675 lb per foot for the 6 Y.G.A. The specific weight of the engines is approximately 10 lb per brake horsepower. A mark 8 Y.G.A. engine is shown in our illustration.

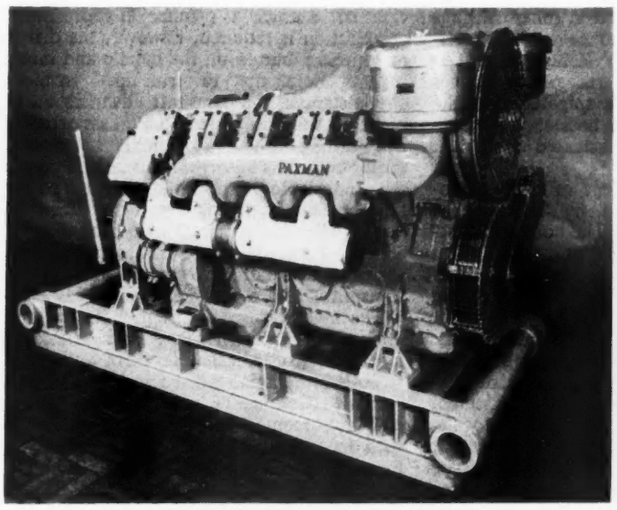
The crankcase is a casting of spheroidal-graphite iron and the individual cylinder heads and barrels are one-piece aluminium alloy castings fitted with shrunk-in hardened and tempered cast iron liners. Economy of air flow to achieve satisfactory cooling determined the development of cylinder head and barrel, with fin disposition and baffle design ensuring that local hot spots are avoided and that the temperature gradients are generally moderate. Again it was air flow requirements which determined the head arrangement of single inlet and exhaust valves, of large area to give volumetric efficiency, mounted at a small inclination to each other and allowing an injector to be fitted centrally. The valves have hardened tips and seat on wear resisting inserts and work in specially hardened guides. Push rods from a one-piece camshaft, carried in pressure lubricated phosphor bearings, operate the valves. Each aluminium alloy piston has four pressure and two oil control rings, the top pressure ring being chromium plated, and a side by side arrangement has been adopted for the connecting rods, which are machined from steel stampings and matched for weight and balance and have phosphor-bronze small end bushes. The underslung



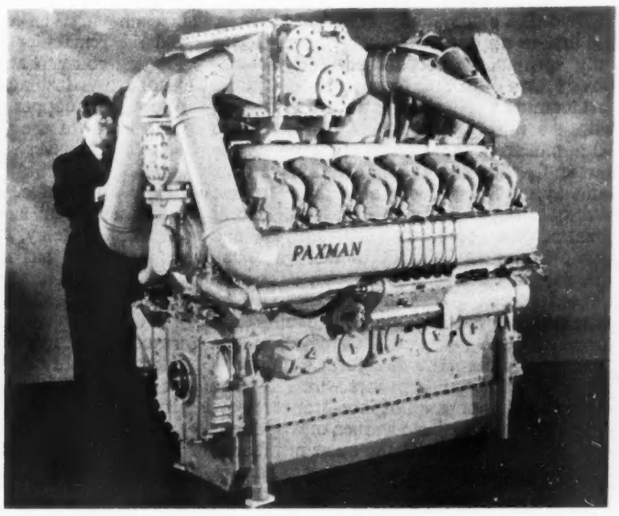
Aluminium alloy cylinder head for "Ventura" engines

crankshaft is of forged steel and all main and large-end bearings are of steel shell copper lead lined and lead-tin flashed pattern. A coupling assembled to the free-end of the shaft carries a viscous torsional vibration damper, while a chain from the crankshaft drives the axial cooling fan, which can deliver 30 cubic feet of air per brake horsepower at 7in water gauge and absorbs about 6 per cent of the engine power. If required the direction of air flow can be reversed.

C.A.V. pattern "NN" fuel injection



Paxman 8 Y.G.A. "Vega" air-cooled V form engine



Paxman 12 Y.J.C. "Ventura" pressure-charged and intercooled V engine

pumps are mounted and used with mechanical or hydraulic governing or governors produced by the Ardleigh Engineering Company, Ltd., where special governing is required. A light alloy sump closes the crankcase, and houses two lubricating oil pumps, one of which circulates the oil to bearings at high pressure and the other circulates the oil at low pressure through an air-cooled oil cooler. Starting is by a 24V 6in electric starter motor and there is a 5½in dynamo for battery charging. The engine can be mounted at an inclination of 1 in 4.

"Ventura" Engines

The greater demand for higher-powered engines, particularly for the oil drilling industry, is largely met by the "Ventura" range of lightweight high-performance units which have dimensions no greater than the company's R.P.H. engines of 7in bore. Besides having a large number of applications for the various power requirements in the oil fields the engines are suitable for powering main line locomotives, diesel train sets, &c. Engines of existing designs already have attained a service life averaging 16,000 hours between overhauls and the new range has had built into them the same degree of operational life. This has been done by extensive rig testing of new parts such as the cylinder head, connecting rod assembly, piston cooling arrangements, cylinder liner strength, &c. There are four engines in the range which consist of twelve- and sixteen-cylinder 60 deg. V form pressure-charged engines, mark Y.J.X., and engines having the same number of cylinders but pressure-charged and intercooled, mark Y.J.C. We illustrate a twelve-cylinder pressure-charged and intercooled unit.

The new units are of open combustion chamber direct injection design having a bore and stroke of 7¾in by 8½in, a firing pressure of 1250 lb per square inch and a speed of 1500 r.p.m. and the table below gives horsepower ratings.

Engine mark	Industrial ratings at 1500 r.p.m.	Traction ratings at 1500 r.p.m.	Brake mean effective pressure (traction) lb/square in
12 Y.J.X.	1100 b.h.p.	1200 b.h.p.	132
12 Y.J.C.	1300 b.h.p.	1400 b.h.p.	154
16 Y.J.X.	1470 b.h.p.	1600 b.h.p.	132
16 Y.J.C.	1735 b.h.p.	1870 b.h.p.	154

The specific weight varies between 6 lb and 7·15 lb per brake horsepower.

The crankcase and cylinder blocks are of monobloc construction fabricated from machined steel plate and precision steel castings, and the forged steel cylinder liners are chromium plated internally and externally and the bore treated for oil retention. Two inlet and two face-hardened exhaust valves are carried on the high strength aluminium alloy cylinder head, which has aluminium bronze valve seat inserts and valve guides. Each pair of valves is operated by a push rod and single rocker from a centrally mounted camshaft supported in thin wall bearings. The valve gear cover is shaped to allow the injector to be mounted centrally outside it, so that the possibility of fuel dilution is eliminated. The arrangement of the cylinder head can be seen in our illustration.

Three compression and two oil control rings are fitted to the aluminium alloy pistons, which have a cast iron top ring insert and are cooled by a metered quantity of oil through the connecting rods. The latter are of fork and blade pattern forged in high tensile steel and fully balanced, and can be withdrawn through the cylinder bores. Balance weights are on all the webs of the forged nickel-chrome high tensile steel crankshaft, which has journals and pins induction hardened and ground. Thin shell copper lead lined large-end and main bearings are used with an additional main bearing at the drive end. The sump is fabricated in light alloy.

Monobloc C.A.V. fuel injection pumps are provided for each cylinder bank and gear driven, and a fuel lift pump is driven from the free end. An Ardleigh governor is fitted. For lubrication purposes there are two pumps located at the drive end of the engine; one supplies the high-pressure oil to the bearings and the other circulates the oil through the cooler. A thermostatic control valve is incorporated in the cooling system in which a single pump circulates water to the inlet manifold of each cylinder bank.

Each twelve-cylinder engine has one turbo-charger while the sixteen-cylinder unit has two. The turbo-chargers are of aluminium alloy and the pressure ratio is 2½ to 1.

Motor-Generator Locomotives for Kent Coast Electrification

THE first of thirteen B_0–B_0 mixed traffic locomotives under construction by British Railways at Doncaster for the 660/750V d.c. Kent Coast electrification of the Southern Region is now undergoing trials. Being required to work freight trains of up to 900 tons as well as express freight and passenger services, the locomotive has been designed with flexible operating characteristics and uses a motor-generator booster control system similar to that of the three earlier C_0–C_0 units operating in the Central Section of the Region. This arrangement has enabled thirty-three running notches to be provided, while also meeting the need for maintaining traffic effort, by means of flywheels on the motor and generator shafts, while negotiating gaps in the conductor rail.

As in the previous series, the wide range of control is obtained by buck-and-boost connection of the generator output relative to the 675V (nominal) live-rail supply, but in the new locomotive a single motor-generator set supplies four traction motors in parallel pairs as compared with the earlier arrangement of two motor-generator sets each supplying the three series-connected traction motors in one bogie. Some leading particulars of the locomotive are tabulated below :

Length over buffers	50ft 7in
Bogie centres	27ft 0in
Bogie wheelbase	10ft 6in
Total wheelbase	37ft 6in
Weight in working order	77 tons
One-hour rating of locomotive	2552 h.p.
Tractive effort (nominal maximum)	43,000 lb at 25 per cent adhesion
Tractive effort (one-hour)	20,000 lb at 47 m.p.h.
Balancing speed with 500-ton passenger train	80 m.p.h.
Maximum service speed	90 m.p.h.

The progress in all aspects of electric locomotive design in the past ten years is typified by the power/weight ratio given above in comparison with the one-hour output of 1470 h.p. for a weight of 105 tons produced by the third of the previous locomotives (described in THE ENGINEER of March 11, 1949). Both in mechanical and certain electrical details the new type may be regarded as a forerunner of the new generation of locomotives now being built for the 50 c/s

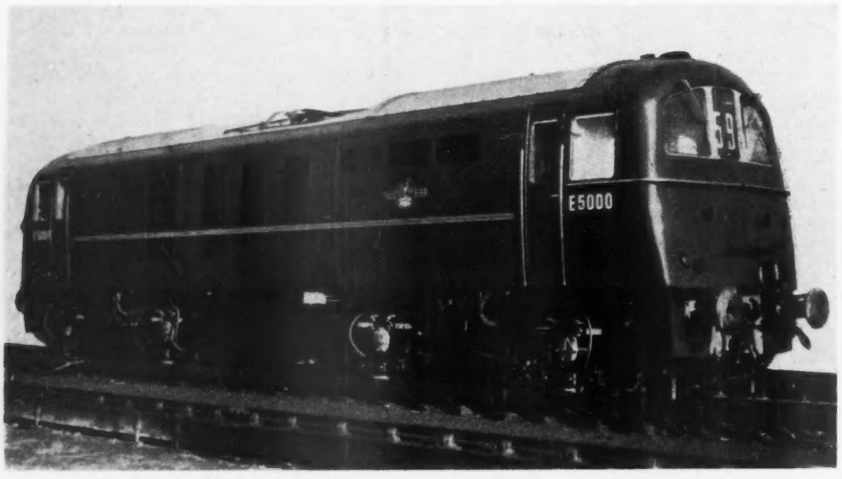
high-voltage a.c. system. It is, for example, the first to appear on British Railways with fully springborne motors and the Brown-Boveri form of flexible drive to be used in the forthcoming a.c. designs, a feature in keeping with the raising of the maximum speed to 90 m.p.h. from the limit of 75 m.p.h. in the earlier C_0–C_0 series. The drives have been built by the Swiss Locomotive and Machine Works. Bogie design also follows recent practice for four-axle locomotives and acknowledgment is made to the advice on this subject received from S.L.M. The axleboxes, axlebox guides and primary suspension components have been manufactured at Doncaster under licence from that company. Axlebox guides take the form of circular pillars, and the guide bushes which slide on them consist of a phosphor-bronze sleeve pressed into the inner member of a specially designed "Silentbloc," the outer member of which is carried in an annular housing forming part of the axlebox casing. Working surfaces are continuously lubricated from an oil reservoir.

In place of the segmental pivot characteristic of the previous Southern Region electric locomotive design, the bogie pivoting arrangement consists of a steel casting and a large "Spherilastik" bearing, located in the bolster at approximately axle height, which takes the traction and braking forces. These forces are transmitted from the bogie frame to the bolster by two horizontal links, 2ft 6in long, fitted at each end with "Spherilastik" bushes.

The bolster carries two spherically-seated pads to take the weight of the main underframe. Both the spherical and flat surfaces of the pads are lined with non-metallic friction materials. Any tendency for the bogie to hunt when rotating is resisted by the friction linings on the flat surfaces. The ends of the bolster bear on the centre buckles of two inverted laminated springs having 5ft centres, the ends of which are carried by four inclined swing links with "Spherilastik" bushes at both ends, and a rectangular rubber pad is provided at the spring seatings. Lateral movement of the bolster is limited to 1½in each way by rubber buffers. The first two locomotives are being fitted experimentally with Woodhead-Monroe hydraulic dampers to damp out lateral oscillations of the bolster.

Of the thirteen locomotives being built initially, seven are to be fitted with axleboxes having Timken tapered roller bearings and the remainder are to have S.K.F. self-aligning roller bearings. Return current is carried by insulated earth return bushes bearing on copper rings spigoted into the outer faces of the wheel bosses. The axleboxes themselves are insulated from the frame.

The electrical equipment of the locomotives has been supplied by The English Electric Company, Ltd. The booster motor-generator set has an output of 945kW at 1750 r.p.m. An electro-pneumatically operated rim brake acts on each flywheel when it is desired to stop the set quickly. Supplies for control purposes and battery charging are taken from an auxiliary generator overhung on the main generator. An electrically-driven camshaft cuts out six steps of resistance under time control for starting the booster set and also restores the resistance while running over gaps in readiness for accelerating the set to normal speed again when the conductor rail is regained.



The first of thirteen locomotives for mixed traffic service on Southern Region main lines to the Kent coast now being electrified on the third-rail d.c. system

The four traction motors are six-pole machines rated at 638 h.p. (one-hour) at 675V and are connected in two parallel pairs. The booster generator is in series between the two motor circuits and the motor voltage is controlled by bucking or boosting the line supply by variation of the generator excitation.

Since the locomotive has thirty-three running notches (including four weak-field steps) as against twenty-six in the third of the previous series, a handwheel controller of the design formerly used would have been inconveniently bulky and, therefore, a new form of control has been adopted in which a motor-driven camshaft has replaced individual electro-pneumatic contactors. The driver's controller now has two handles, one of which is a four-position master switch ("off," "forward," "neutral" and "reverse"), and the other is the main controller handle with five positions ("off," "run back," "hold," "notch up" and "run up"). Having started the motor-generator set and selected forward or reverse running by means of the master switch, the driver moves the main controller handle to "notch up," causing the camshaft to advance one notch. If the handle is now moved to and fro between the "notch up" and "hold" positions, the locomotive can be accelerated at any desired rate, each complete motion of the handle causing further progression of the camshaft a notch at a time. If more rapid acceleration is required, however, the driver may press a button on the handle and move it past "notch up" to "run up." In these circumstances, the camshaft advances automatically to the highest notch unless arrested by returning the handle to "hold" if excessive motor current is observed. To reduce power the handle is moved to "run back," or, if power is to be shut off completely, it is returned to "off" when the camshaft runs back to zero. The position of the control camshaft is indicated to the driver by means of a Desynn transmitter and dial indicator.

The system described represents the first application to a British Railways electric locomotive of camshaft control with continuous progression when required, and is in line with Continental practice, both in d.c. and a.c. locomotives. A similar method is used in the most recent 1500V d.c. B_0–B_0 locomotives of the French National Railways, and in 3000V d.c. designs of the Belgian National Railways. In the Belgian case the automatic facility is used normally, the rate of acceleration being selected by the driver by means of a control which adjusts the setting of the accelerating relay. A similar practice is now being followed in Belgian-built a.c. locomotives for overseas, and it would therefore appear that the system has proved a practical compromise between the alternatives of manual control and fully automatic acceleration. In the new Southern Region locomotive a controller of simpler form, without the "run-up" position, is provided on the off-side of the cab for use in shunting.

The layout of the two cabs is identical. Desks are provided on both sides, that on the off-side having the simplified controller mentioned above and a hand brake wheel. Dead man's pedals are duplicated. Provision is made for supplying train heating current from the locomotive.

In addition to eight lightweight sprung collector shoes for current collection from the live rail, the locomotive is fitted with a double-pan pantograph for use with an overhead contact wire on approach roads to goods and marshalling yards.

The design of the locomotive was carried out under the direction of Mr. W. J. A. Sykes, Chief Mechanical and Electrical Engineer, Southern Region, in consultation with Mr. R. C. Bond, who was Chief Mechanical Engineer, British Railways Central Staff, at the time the design was prepared, and Mr. S. B. Warder, Chief Electrical Engineer, British Railways Central Staff.

DESIGN COMPETITION FOR AN ELEVATED MOTORWAY.—The Prestressed Concrete Development Group, Terminal House, Grosvenor Gardens, London, S.W.1, is sponsoring a design competition for a length of elevated road forming part of an urban motorway. The competition stipulates that prestressed concrete must be used in the design, and gives other detailed design requirements for (*a*) an elevated road on the same line as an existing road and carried above it on piers in the central strip, the lower road to carry traffic during and after construction, and (*b*) a length of this road short-circuiting the lower road so that a more economic arrangement for the supports can be adopted, limited only by the requirement that the area below the elevated road can be used as a car park. The assessors are Mr. H. C Adams (Ministry of Transport), Mr. C. P. Andren (traffic engineer, University College, London), Mr. A. G. Jury (city architect, Glasgow), Col. G. W. Kirkland (president of the Group), and Sir Herbert Manzoni (city engineer, Birmingham). One or two premiums of £500 will be awarded, the entries being required by June 30. This is the second competition which has been promoted with the general aim of stimulating interest in urban motorways; recently, the Roads Campaign Council announced a competition for a solution to traffic problems in central London, and entries for this, more general, problem, are due to be received in the Spring.

SHORTER REPORTS

Hot Experimental Reactor of Zero Power, "HERO"

A NEW low-power research reactor, known as "HERO" (Hot Experimental Reactor of zero power), is to be built at the United Kingdom Atomic Energy Authority's Windscale site, which is being expanded as one of the national centres for the development of gas-cooled reactors. "HERO" will be built near the Advanced Gas Cooled Reactor (A.G.R.), work upon which has already begun. The function of "HERO" will be complementary to that of A.G.R. It will be recalled that A.G.R. is essentially a reactor for fuel element development under reactor working conditions; it is designed to work at power levels corresponding to 100,000kW of heat (30,000kW electrical). "HERO" will facilitate the making of measurements at low radiation levels and will enable experiments to be made with several alternative arrangements of fuel elements to obtain optimum results.

"HERO," which will generate a few kilowatts of heat, will consist initially of a graphite structure 19ft in diameter and 19ft high, but an important provision is that it will be possible to dismantle and rebuild it in a variety of ways. The graphite core will be contained in a steel vessel connected to a ventilating circuit with pumps and heaters, so that it can be operated at high temperature in carbon dioxide. It will, in fact, be the reverse of the A.G.R. since the carbon dioxide gas will supply heat to the core instead of removing heat from it. As in A.G.R., the fuel will consist of clusters of rods of uranium oxide sealed into beryllium cans, and these will be arranged in channels in the graphite on a regular lattice.

It is estimated that "HERO" will be completed in 1961, at a cost of about £1,250,000.

St. Lawrence Seaway

THE St. Lawrence Seaway Authority has stated that construction of works under its jurisdiction has progressed to a stage which assures that all channels, locks and ancillary structures of the seaway will be available to shipping at the opening of navigation next spring, although subject, in part, to a restricted depth of 24ft 6in until June 1, when the specified minimum depth of 27ft will be available throughout. A statement to this effect was made on January 20 in the Canadian House of Commons by Mr. George Hees, Minister of Transport. He said that before vessels might safely use the new seaway aids to navigation had to be placed, which was a responsibility of the Department of Transport. Every effort would be made to have that work completed, he said, as near as possible to the time when navigation would normally have commenced. The objective for the completion of that work was not later than April 20, dependent, of course, on weather and ice. However, in accordance with established canal operation practice, a more precise statement of the opening date could be expected toward the end of March.

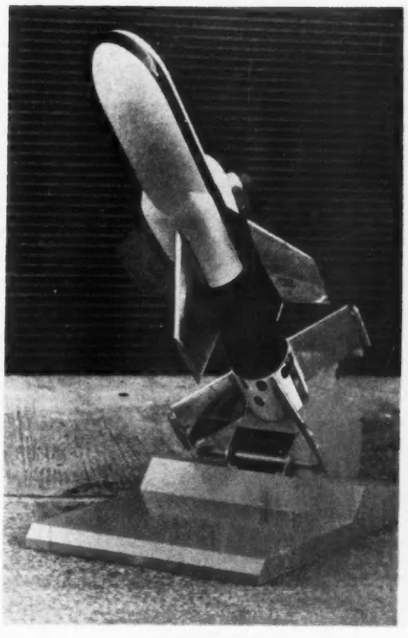
National College of Agricultural Engineering

THE Minister of Education, Mr. Geoffrey Lloyd, announced on Tuesday that it had been decided to establish a National College of Agricultural Engineering. Premises for the college are to be built at Silsoe, Bedfordshire, near to the National Institute of Agricultural Engineering. The cost of the project is put at £250,000 and, initially, provision is to be made for between sixty and 100 students from this country and from overseas who will take advanced courses leading to a diploma. The cost of the land and the building will fall primarily on the Exchequer, though the agricultural engineering industry has assured the Minister of its willingness to make a substantial contribution in terms of equipment. The industry has also indicated its willingness to support each year a number of sandwich course students. The Ministry of Education acknowledges that the college has become necessary in order to meet the growing requirement for fully qualified agricultural engineers; the continued expansion of the export business of the agricultural engineering industry has been a particularly influential factor in finally deciding to establish the college. Sir Eric Ashby, vice-chancellor of Queen's University, Belfast, and Master-Elect of Clare College, Cambridge, is to be the chairman of the governing body of the new college. The Minister's announcement follows discussions which have been going on for some years with the Ministry of Agriculture, Fisheries and Food, the Institution of British Agricultural Engineers and the Agricultural Engineers Association.

Naval Anti-Aircraft Missile

IT was announced last week that the 40mm defensive armament of the Royal Navy is to be replaced by a close-range surface-to-air missile known as the Short "Seacat." It is intended both as a support for the outer ring of defensive fighters and long-range missiles, and as a weapon for small ships. Its introduction is anticipated in the "early 1960s." A variant known as the "Tigercat" is being investigated by Short Brothers and Harland as a replacement for light guns in the Army.

A test vehicle used in the evolution of the "Seacat" is illustrated here. There is reason to



The Short "SX-A5" multi-purpose test vehicle. Notice the aircraft-style light alloy construction and the fairings in abutment with which the wings move

believe that this vehicle is command-guided with a human operator to close the loop: tracking flares are visible in the illustration. Such a system would appear to be quite valueless in the Naval role, since the fighter screen may be least effective in fog, precipitation and heavy seas, and even in good weather from the control platform of a large warship it would appear impossible to execute a collision interception at a relative speed of, say, 1000 m.p.h. If terminal homing is included, infra-red could be discarded on the same grounds of inadequate performance, but it would be surprising if so small a vehicle were to carry the only active homing set ever produced in Great Britain. The statement that it is an "ingenious weapon with a novel type of direction" can therefore be accepted.

Electronics and Communications Section of the I.E.E.

AT a meeting of its council last week the Institution of Electrical Engineers decided that the name of the "Radio and Telecommunications Section" of the Institution should be changed to "Electronics and Communications Section." The first word in the new title acknowledges the fact that in recent years the term "electronics" has been generally applied to cover the wider industrial use of techniques that were, formerly, almost exclusive to radio engineering. The use of this word also implies that the I.E.E. is the appropriate learned society for those properly qualified electrical engineers who regard themselves as electronics engineers. The word "radio" has been omitted because, with its modern connotation it is thought to be too narrow to describe the scope of the section: interests such as navigational aid and radar are implicit in the new title. Finally, it is thought that the use of the shorter word "communications" (instead of "telecommunications") is justified in the context of electrical engineering.

Institution of Electrical Engineers

THE council of the Institution of Electrical Engineers has elected Mr. Charles W. Speirs, at the age of eighty-five, to honorary membership of the Institution in recognition of his contributions to the advancement of electrical science and engineering and his outstanding support of the work of the Institution, particularly of its Incorporated Benevolent Fund. In 1944, eleven years after his retirement from the staff of the Morgan Crucible Company, Ltd., he made a substantial gift of land from his estate at Malden accompanied by a handsome endowment, which, when supplemented by contributions of I.E.E. members, provided the means for establishing "The Chesters" as a residential estate for beneficiaries of the I.E.E. Incorporated Benevolent Fund. The council has also made the thirty-seventh award of the Faraday Medal to Signor Luigi Emanueli for his outstanding inventions and new applications in electrical cables and particularly for the invention of the oil-filled cable.

Longer-Term D.S.I.R. Grants

IT is announced that longer-term grants for special researches will be awarded by the Department of Scientific and Industrial Research in future. These grants—which have normally been limited to a maximum of five years—may now be awarded for an initial period of up to seven years with the possibility of continuing support for a further ten years. The first closing date for applications is March 1. This change in policy has been made to meet present-day needs. The more complex and expensive researches may require support for more than five years to become fully established. When fully established the support for these researches will be transferred from D.S.I.R. to the university; arrangements are being worked out to simplify such transfer. The Department is therefore willing to support for longer periods outstanding university investigators embarking on promising researches for which their universities are unable to make adequate provision.

The main conditions are:

An initial award for periods of three to seven years, with the possibility of two renewals, each of a maximum duration of five years. A third renewal would not normally be given.

Details of the scheme are contained in the 1959 edition of *Notes on D.S.I.R. Grants*, published by H.M. Stationery Office in January.

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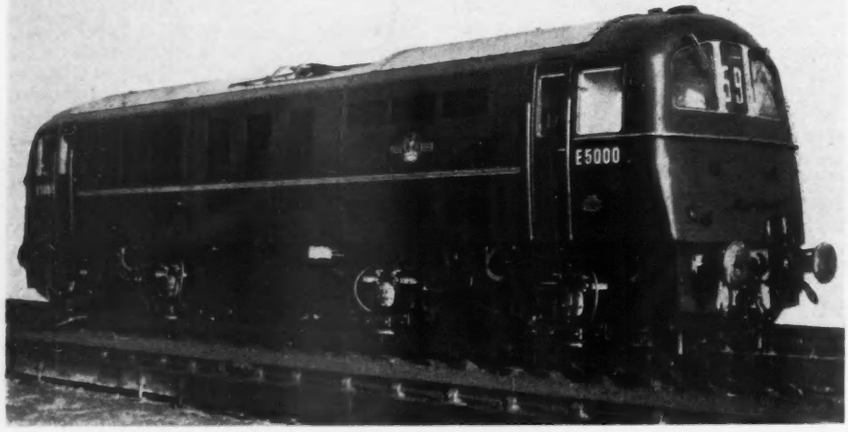
Of the thirteen locomotives being built initially, seven are to be fitted with axleboxes having Timken tapered roller bearings and the remainder are to have S.K.F. self-aligning roller bearings. Return current is carried by insulated earth return bushes bearing on copper rings spigoted into the outer faces of the wheel bosses. The axleboxes themselves are insulated from the frame.

The electrical equipment of the locomotives has been supplied by The English Electric Company, Ltd. The booster motor-generator set has an output of 945kW at 1750 r.p.m. An electro-pneumatically operated rim brake acts on each flywheel when it is desired to stop the set quickly. Supplies for control purposes and battery charging are taken from an auxiliary generator overhung on the main generator. An electrically-driven camshaft cuts out six steps of resistance under time control for starting the booster set and also restores the resistance while running over gaps in readiness for accelerating the set to normal speed again when the conductor rail is regained.



The first of thirteen locomotives for mixed traffic service on Southern Region main lines to the Kent coast now being electrified on the third-rail d.c. system

The four traction motors are six-pole machines rated at 638 h.p. (one-hour) at 675V and are connected in two parallel pairs. The booster generator is in series between the two motor circuits and the motor voltage is controlled by bucking or boosting the line supply by variation of the generator excitation.

Since the locomotive has thirty-three running notches (including four weak-field steps) as against twenty-six in the third of the previous series, a handwheel controller of the design formerly used would have been inconveniently bulky and, therefore, a new form of control has been adopted in which a motor-driven camshaft has replaced individual electro-pneumatic contactors. The driver's controller now has two handles, one of which is a four-position master switch ("off," "forward," "neutral" and "reverse"), and the other is the main controller handle with five positions ("off," "run back," "hold," "notch up" and "run up"). Having started the motor-generator set and selected forward or reverse running by means of the master switch, the driver moves the main controller handle to "notch up," causing the camshaft to advance one notch. If the handle is now moved to and fro between the "notch up" and "hold" positions, the locomotive can be accelerated at any desired rate, each complete motion of the handle causing further progression of the camshaft a notch at a time. If more rapid acceleration is required, however, the driver may press a button on the handle and move it past "notch up" to "run up." In these circumstances, the camshaft advances automatically to the highest notch unless arrested by returning the handle to "hold" if excessive motor current is observed. To reduce power the handle is moved to "run back," or, if power is to be shut off completely, it is returned to "off" when the camshaft runs back to zero. The position of the control camshaft is indicated to the driver by means of a Desynn transmitter and dial indicator.

The system described represents the first application to a British Railways electric locomotive of camshaft control with continuous progression when required, and is in line with Continental practice, both in d.c. and a.c. locomotives. A similar method is used in the most recent 1500V d.c. B_0–B_0 locomotives of the French National Railways, and in 3000V d.c. designs of the Belgian National Railways. In the Belgian case the automatic facility is used normally, the rate of acceleration being selected by the driver by means of a control which adjusts the setting of the accelerating relay. A similar practice is now being followed in Belgian-built a.c. locomotives for overseas, and it would therefore appear that the system has proved a practical compromise between the alternatives of manual control and fully automatic acceleration. In the new Southern Region locomotive a controller of simpler form, without the "run-up" position, is provided on the off-side of the cab for use in shunting.

The layout of the two cabs is identical. Desks are provided on both sides, that on the off-side having the simplified controller mentioned above and a hand brake wheel. Dead man's pedals are duplicated. Provision is made for supplying train heating current from the locomotive.

In addition to eight lightweight sprung collector shoes for current collection from the live rail, the locomotive is fitted with a double-pan pantograph for use with an overhead contact wire on approach roads to goods and marshalling yards.

The design of the locomotive was carried out under the direction of Mr. W. J. A. Sykes, Chief Mechanical and Electrical Engineer, Southern Region, in consultation with Mr. R. C. Bond, who was Chief Mechanical Engineer, British Railways Central Staff, at the time the design was prepared, and Mr. S. B. Warder, Chief Electrical Engineer, British Railways Central Staff.

DESIGN COMPETITION FOR AN ELEVATED MOTORWAY.—The Prestressed Concrete Development Group, Terminal House, Grosvenor Gardens, London, S.W.1, is sponsoring a design competition for a length of elevated road forming part of an urban motorway. The competition stipulates that prestressed concrete must be used in the design, and gives other detailed design requirements for (*a*) an elevated road on the same line as an existing road and carried above it on piers in the central strip, the lower road to carry traffic during and after construction, and (*b*) a length of this road short-circuiting the lower road so that a more economic arrangement for the supports can be adopted, limited only by the requirement that the area below the elevated road can be used as a car park. The assessors are Mr. H. C Adams (Ministry of Transport), Mr. C. P. Andren (traffic engineer, University College, London), Mr. A. G. Jury (city architect, Glasgow), Col. G. W. Kirkland (president of the Group), and Sir Herbert Manzoni (city engineer, Birmingham). One or two premiums of £500 will be awarded, the entries being required by June 30. This is the second competition which has been promoted with the general aim of stimulating interest in urban motorways; recently, the Roads Campaign Council announced a competition for a solution to traffic problems in central London, and entries for this, more general, problem, are due to be received in the Spring.

SHORTER REPORTS

Hot Experimental Reactor of Zero Power, "HERO"

A NEW low-power research reactor, known as "HERO" (Hot Experimental Reactor of zero power), is to be built at the United Kingdom Atomic Energy Authority's Windscale site, which is being expanded as one of the national centres for the development of gas-cooled reactors. "HERO" will be built near the Advanced Gas Cooled Reactor (A.G.R.), work upon which has already begun. The function of "HERO" will be complementary to that of A.G.R. It will be recalled that A.G.R. is essentially a reactor for fuel element development under reactor working conditions ; it is designed to work at power levels corresponding to 100,000kW of heat (30,000kW electrical). "HERO" will facilitate the making of measurements at low radiation levels and will enable experiments to be made with several alternative arrangements of fuel elements to obtain optimum results.

"HERO," which will generate a few kilowatts of heat, will consist initially of a graphite structure 19ft in diameter and 19ft high, but an important provision is that it will be possible to dismantle and rebuild it in a variety of ways. The graphite core will be contained in a steel vessel connected to a ventilating circuit with pumps and heaters, so that it can be operated at high temperature in carbon dioxide. It will, in fact, be the reverse of the A.G.R. since the carbon dioxide gas will supply heat to the core instead of removing heat from it. As in A.G.R., the fuel will consist of clusters of rods of uranium oxide sealed into beryllium cans, and these will be arranged in channels in the graphite on a regular lattice.

It is estimated that "HERO" will be completed in 1961, at a cost of about £1,250,000.

St. Lawrence Seaway

THE St. Lawrence Seaway Authority has stated that construction of works under its jurisdiction has progressed to a stage which assures that all channels, locks and ancillary structures of the seaway will be available to shipping at the opening of navigation next spring, although subject, in part, to a restricted depth of 24ft 6in until June 1, when the specified minimum depth of 27ft will be available throughout. A statement to this effect was made on January 20 in the Canadian House of Commons by Mr. George Hees, Minister of Transport. He said that before vessels might safely use the new seaway aids to navigation had to be placed, which was a responsibility of the Department of Transport. Every effort would be made to have that work completed, he said, as near as possible to the time when navigation would normally have commenced. The objective for the completion of that work was not later than April 20, dependent, of course, on weather and ice. However, in accordance with established canal operation practice, a more precise statement of the opening date could be expected toward the end of March.

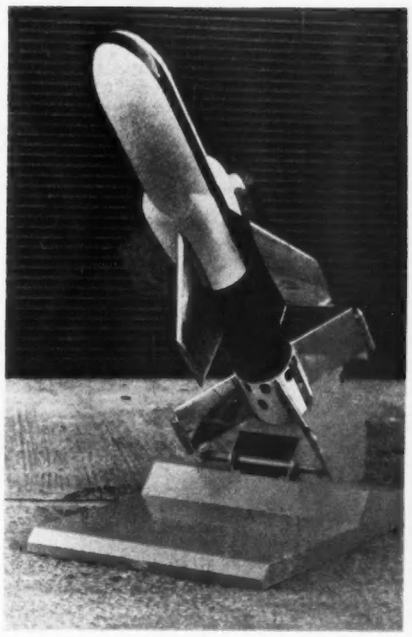
National College of Agricultural Engineering

THE Minister of Education, Mr. Geoffrey Lloyd, announced on Tuesday that it had been decided to establish a National College of Agricultural Engineering. Premises for the college are to be built at Silsoe, Bedfordshire, near to the National Institute of Agricultural Engineering. The cost of the project is put at £250,000 and, initially, provision is to be made for between sixty and 100 students from this country and from overseas who will take advanced courses leading to a diploma. The cost of the land and the building will fall primarily on the Exchequer, though the agricultural engineering industry has assured the Minister of its willingness to make a substantial contribution in terms of equipment. The industry has also indicated its willingness to support each year a number of sandwich course students. The Ministry of Education acknowledges that the college has become necessary in order to meet the growing requirement for fully qualified agricultural engineers ; the continued expansion of the export business of the agricultural engineering industry has been a particularly influential factor in finally deciding to establish the college. Sir Eric Ashby, vice-chancellor of Queen's University, Belfast, and Master-Elect of Clare College, Cambridge, is to be the chairman of the governing body of the new college. The Minister's announcement follows discussions which have been going on for some years with the Ministry of Agriculture, Fisheries and Food, the Institution of British Agricultural Engineers and the Agricultural Engineers Association.

Naval Anti-Aircraft Missile

IT was announced last week that the 40mm defensive armament of the Royal Navy is to be replaced by a close-range surface-to-air missile known as the Short "Seacat." It is intended both as a support for the outer ring of defensive fighters and long-range missiles, and as a weapon for small ships. Its introduction is anticipated in the "early 1960s." A variant known as the "Tigercat" is being investigated by Short Brothers and Harland as a replacement for light guns in the Army.

A test vehicle used in the evolution of the "Seacat" is illustrated here. There is reason to believe that this vehicle is command-guided with a human operator to close the loop : tracking flares are visible in the illustration. Such a system would appear to be quite valueless in the Naval role, since the fighter screen may be least effective in fog, precipitation and heavy seas, and even in good weather from the control platform of a large warship it would appear impossible to execute a collision interception at a relative speed of, say, 1000 m.p.h. If terminal homing is included, infra-red could be discarded on the same grounds of inadequate performance, but it would be surprising if so small a vehicle were to carry the only active homing set ever produced in Great Britain. The statement that it is an "ingenious weapon with a novel type of direction" can therefore be accepted.



The Short "SX-A5" multi-purpose test vehicle. Notice the aircraft-style light alloy construction and the fairings in abutment with which the wings move

Electronics and Communications Section of the I.E.E.

AT a meeting of its council last week the Institution of Electrical Engineers decided that the name of the "Radio and Telecommunications Section" of the Institution should be changed to "Electronics and Communications Section." The first word in the new title acknowledges the fact that in recent years the term "electronics" has been generally applied to cover the wider industrial use of techniques that were, formerly, almost exclusive to radio engineering. The use of this word also implies that the I.E.E. is the appropriate learned society for those properly qualified electrical engineers who regard themselves as electronics engineers. The word "radio" has been omitted because, with its modern connotation it is thought to be too narrow to describe the scope of the section : interests such as navigational aid and radar are implicit in the new title. Finally, it is thought that the use of the shorter word "communications" (instead of "telecommunications") is justified in the context of electrical engineering.

Institution of Electrical Engineers

THE council of the Institution of Electrical Engineers has elected Mr. Charles W. Speirs, at the age of eighty-five, to honorary membership of the Institution in recognition of his contributions to the advancement of electrical science and engineering and his outstanding support of the work of the Institution, particularly of its Incorporated Benevolent Fund. In 1944, eleven years after his retirement from the staff of the Morgan Crucible Company, Ltd., he made a substantial gift of land from his estate at Malden accompanied by a handsome endowment, which, when supplemented by contributions of I.E.E. members, provided the means for establishing "The Chesters" as a residential estate for beneficiaries of the I.E.E. Incorporated Benevolent Fund. The council has also made the thirty-seventh award of the Faraday Medal to Signor Luigi Emanueli for his outstanding inventions and new applications in electrical cables and particularly for the invention of the oil-filled cable.

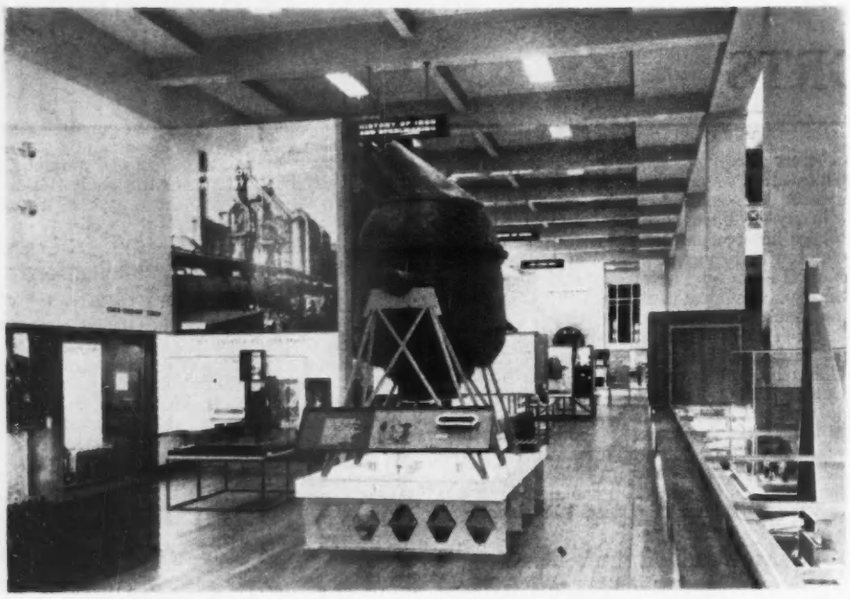
Longer-Term D.S.I.R. Grants

IT is announced that longer-term grants for special researches will be awarded by the Department of Scientific and Industrial Research in future. These grants—which have normally been limited to a maximum of five years—may now be awarded for an initial period of up to seven years with the possibility of continuing support for a further ten years. The first closing date for applications is March 1. This change in policy has been made to meet present-day needs. The more complex and expensive researches may require support for more than five years to become fully established. When fully established the support for these researches will be transferred from D.S.I.R. to the university ; arrangements are being worked out to simplify such transfer. The Department is therefore willing to support for longer periods outstanding university investigators embarking on promising researches for which their universities are unable to make adequate provision.

The main conditions are :

An initial award for periods of three to seven years, with the possibility of two renewals, each of a maximum duration of five years. A third renewal would not normally be given.

Details of the scheme are contained in the 1959 edition of *Notes on D.S.I.R. Grants*, published by H.M. Stationery Office in January.

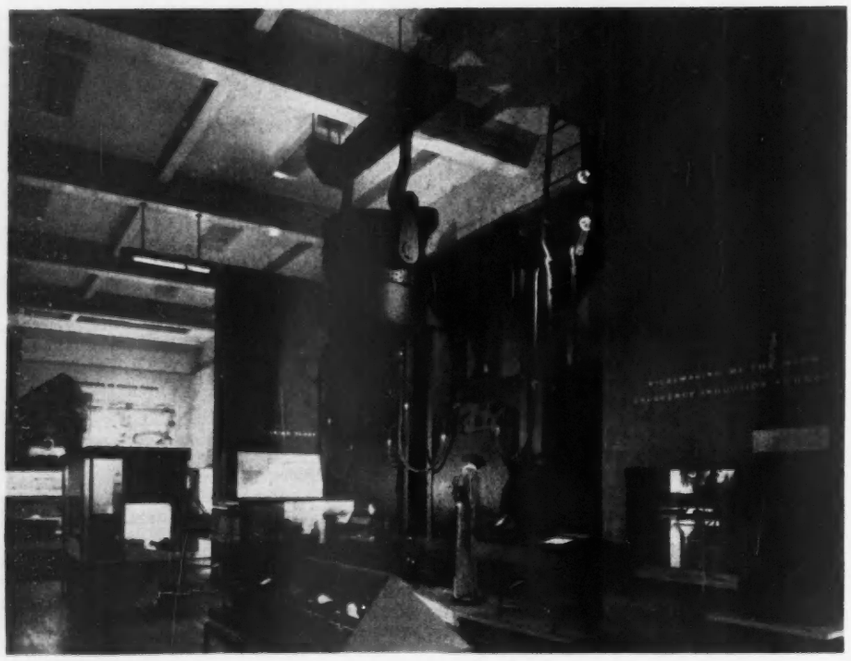


At the Science Museum, South Kensington, the iron and steel exhibits have been rearranged and extended. In the centre of the historical section of the gallery there is a Bessemer converter of 1865

Iron and Steel Gallery at Science Museum

THERE has just been opened at the Science Museum, South Kensington, a newly arranged gallery whose exhibits are devoted to the iron and steel industry. Its purpose is to tell the story of the development of the iron and steel industry from ancient times up to the present day. Formerly the museum devoted 2800 square feet of gallery space to the industry. For the rearranged display 3500 square feet have been made available. Moreover modern display techniques have been used by Publicity Planning, Ltd., which arranged the exhibits to present a consistent and easily comprehended story to the public. The cost (about £60,000) has been principally met by the British Iron and Steel Federation. Some of the exhibits have been drawn from the original Science Museum collection, but others have been contributed by makers and users of steel.

Two photographs of the gallery are reproduced. They show some of the 250-odd exhibits ranging from a slice of meteoric iron to a large alloy steel turbine rotor. At one end of the gallery dioramas and other exhibits illustrate the early history of iron-making. Close by, a complementary section deals with the history of steelmaking. Here one of the largest exhibits is a Bessemer converter of 1865. The central part of the gallery is devoted to modern steelmaking. There is here a full-scale representation of the end of an open-hearth furnace and a working model of a continuous casting plant. In the same section are to be found working models of rolling mills, &c. Finally there are grouped together exhibits dealing with research and metallurgy and the uses of iron and steel.



A full-scale model of the front of an open-hearth furnace dominates the central part of the gallery

Warehouse Structure to Resist Mining Subsidence

A NEW warehouse, built for W. and R. Jacob and Co., Ltd., at Mansfield, Nottinghamshire, has been designed in such a way that complete protection is claimed against the damage due to mining subsidence which would normally occur. The principles employed are, first, to support the whole building on a thin concrete slab which is sufficiently flexible to follow the deflected profile of the ground and strong enough to resist the horizontal forces induced in it by the ground sliding past beneath. Secondly, since the superstructure is therefore called on to resist only differential vertical movements, all the steelwork connections are made as pin joints. The structure then depends for its stability on inclined spring braces, the roof acting as a horizontal beam in both directions, spanning between the perimeter walls containing the braces.

The foundation slab rests on a 6in bed of consolidated sand which has been found experimentally to give the lowest coefficient of friction against horizontal sliding ($\mu = \frac{1}{4}$ approx.) while still using conventional building materials. The sand is retained at the perimeter of the building by a gravel wedge on which paving is placed. Between the slab and the sand is a layer of building paper. The slab is cast in 10ft square panels in " chequer board " pattern. The joints around each panel are painted with bitumen and temporary building paper markers are used to enable the " granolithic " floor finish joints to correspond with those in the slab below. In this way any opening of the joints during subsidence is maintained on a predetermined pattern and no damage occurs to the floor.

The slab is reinforced with high tensile mesh for direct tension only, using a working stress of 45,000 lb per square inch. Compressive forces can be accommodated by the slab without reinforcement.

The steelwork frame is required to take all the roof and wall loads, the horizontal wind forces and be sufficiently flexible to eliminate any build-up of stress due to differential vertical movements in the ground slab.

The 70ft span trusses are of conventional design except at the supports where welded wing plates connect to the box stanchions with a single $\frac{3}{4}$in diameter bolt to form a hinge. The stanchions are positioned by dowels located in plates which are bedded into the floor slab. This permits the stanchions to rock in any direction. The corner stanchions and those which are braced are provided with access panels at their bases. These stanchions are held down by a threaded dowel with a single nut to prevent possible lifting. All the sheeting and glazing angles are connected to the stanchions with single bolts.

No horizontal steel wind bracing is used, the wind forces being transferred to the gable ends by the roof which acts as a horizontal beam. The roof consists of prefabricated wooden panels 10ft square to which are coach-screwed small rectangular steel plates which are, in turn, bolted to the steel trusses to form a continuous rigid diaphragm. The timber panels are, however, sufficiently flexible to accommodate, without damage, any possible differential vertical movements of the trusses.

The whole steel framework depends for its stability on the diagonal spring braces pinned in the side and gable end walls. Each brace consists of two cold rolled channels spaced apart by diaphragm plates. At each end there is a sliding fork attached to a spring which can be precompressed by tightening the locking nut. The springs are arranged to act in compression, one only at a time, depending on whether the brace acts as a tie or a strut. The springs are preloaded to 2 tons so that no movement takes place in the brace until this load is exceeded, i.e. it behaves as a fixed brace. Sufficient braces are put in the perimeter walls so that this load of 2 tons per brace is not exceeded for wind loads only. When subsidence takes place this 2-ton load is exceeded and the brace varies in length to allow the framework to " lozenge." Throughout the time that the framework is in a deformed shape the braces are trying to regain their original length and thereby pull the building back to the vertical. This they are able to do when the subsidence wave has passed and the floor slab is once again horizontal.

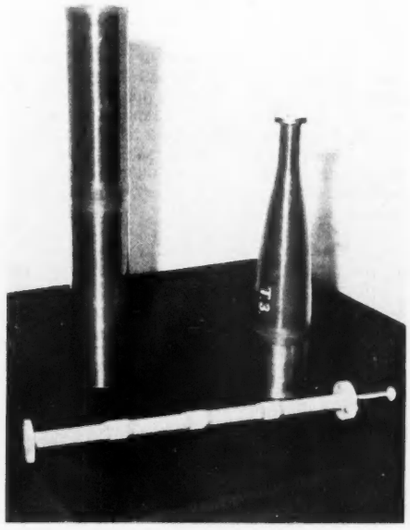
Walls should have no stiffening effect for this design, thus excluding the use of brickwork and similar solid wall construction. The external skin of the warehouse walls is composed of over-

lapping precast concrete units hung from lugs welded to the stanchions. For the inner skin lining "Bellrock" panels are used which are clipped to sheeting rails behind. The stanchions require protection against fire and to avoid the excess load and stiffening effects of concrete the stanchions are cased using sprayed asbestos.

The Mansfield warehouse is expected to be subjected to a maximum vertical subsidence of about 2ft 9in with a maximum differential vertical movement of approximately 4in. The total cost, it is stated, was only slightly above that of a similar building in an area where there is no subsidence and was considerably less than designs using previous methods. The complete warehouse has an area of over 13,000 square feet and was completed in five months. Considerable assistance was made available throughout all phases in its design by the Nottinghamshire County Architects, the Building Research Station, the National Coal Board, and the manufacturers of the braces, Brockhouse Steel Structures, Ltd. The project was in the hands of C.A.S. (Industrial Developments), Ltd., the consulting engineers being Messrs. Andrews, Kent and Stone, and the contractor R. M. Douglas (Contractors), Ltd.

Waveguide Transmission Demonstrations

ON January 31 delegates to the I.E.E. convention on long-distance transmission by waveguide (see THE ENGINEER of January 30) attended demonstrations arranged by Standard Telecommunication Laboratories, Ltd., to show the stage reached by the company in developing a communication system of this kind over the past five years. The demonstrations were held at Frogmore Hall, near Watton-at-Stone, Herts, where a loop of 3600ft (over ¾ mile) of waveguide has been laid down. This loop consists of a 1800ft length of helical anodised aluminium wire guide, and a 1800ft length of plain aluminium tube. Two specially designed right angle corners, at the far end, return the signal from the helical



Components for coupling transmitter output to waveguide. In foreground, twist transducer (rectangular to circular H_{01} mode). At rear, two-section conical taper (right) and helical waveguide with joint (left)

to the plain guide. The helical guide follows a slightly curving path in order to demonstrate the manner in which this form of construction minimises the generation of unwanted modes at bends and discontinuities.

A television signal was transmitted round the loop using the modulation system known as Pulse Code Modulation (P.C.M.). In this system the signal amplitudes are sampled at a frequency a little more than double the top frequency component of interest, and the amplitude samples are converted into a two-level code, which then modulates the output of a C.W. millimetre-wave oscillator feeding the waveguide through an amplifier. At the receiving end the code pulses are used to regenerate the original signal. Since the pulses form a simple on/off code, distortion to which they may be subjected in the waveguide does not appear in the regenerated signal, and the pulses themselves can be reshaped in the receiving apparatus to conform more closely to their original square-wave form, again without prejudice to the resultant signal.

In the demonstration equipment the sampling frequency is 5 Mc/s and the picture waveform is sampled every 200 milli-microseconds. At present the gradation of the picture is reproduced at sixteen levels. This gave a completely acceptable result even when viewed side by side with a television picture containing the full range of tonal values. The quality is not, however, good enough for long distance transmission standards, and an improved version of the equipment is under development using a 10 Mc/s sampling frequency and coding at fifty-four levels.

It is hoped ultimately to transmit a 12 Mc/s video signal in a 300 Mc/s transmitted band, with the individual bands separated by, perhaps, 500 Mc/s. With a usable spectrum in the pipe of 30,000 to 80,000 Mc/s, this gives a capacity per waveguide of 400 television channels, with 3 Mc/s video, or the equivalent in other services. The expectation is that repeaters could be spaced at approximately 20-mile intervals, compared with 3 miles in a coaxial link, which could accommodate only three television channels. The wide bandwidth available in the waveguide system is one of its most valuable characteristics, justifying the effort being devoted to its development in the light of the saturation of available communication channels and the increasing demand for new facilities. A single waveguide link could accommodate large numbers of communication services such as telephone, teleprinter and computer channels.

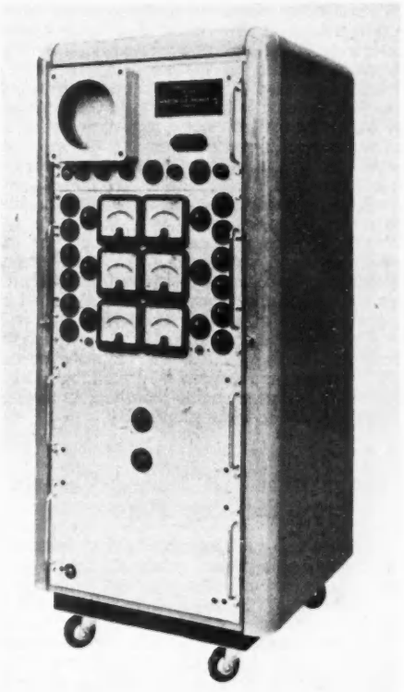
In the demonstration at Frogmore Hall about half a mile of the waveguide pipe used was of the helical wire type, using anodised aluminium wire coated on the outside with an Epoxy type resin. It is being wound at present in 10ft lengths, and the parting cut on completion of winding follows the helix so that adjacent sections butt up to one another without discontinuity of the helical form. Joints are made with the help of a mandrel, the diameter of which can be varied by means of a key. The two ends are slipped over the mandrel, brought into contact, and turned so that the two steps formed by the helical cuts match exactly. Expanding the mandrel by a few thousandths of an inch (using the extractor rod to turn the key) results in accurate alignment of the two waveguide cross-sections. Joints are bound with glass tape to give strength. The experimental pipes, of approximately 2¾in internal diameter, are laid above ground, but a commercially produced system would normally be provided with adequate mechanical strength and protection to allow it to be buried.

The working frequency of the demonstration equipment was around 35,000 Mc/s (8·6mm wavelength). Shorter lengths of helical and plain aluminium guide are used for the examination of pulse reflections. These lengths terminate with a non-contact short circuit formed by a motor-driven piston under remote control. By this means the effective length of the guide can be varied so that reflected pulses can be accentuated in relation to other noise effects and displayed by the oscilloscope on an enlarged scale.

Pulses are launched into the system by means of a rectangular-to-circular mode transducer and a two-section conical taper. Examples of these are illustrated together with two jointed sections of helical waveguide.

Transistor Test Equipment

FOR the rapid and convenient measurement of transistor characteristics, Winston Electronics, Ltd., Shepperton, Middlesex, has developed a curve tracer (type 1006), with oscilloscope, which can be set up to provide the display required in less than a minute. Complete data are given, both for *p–n–p* and *n–p–n* transistors. The curve intensity, as seen on the 6in flat-face cathode-ray tube, is variable to suit viewing or photography, and the hood which shields the tube from unwanted illumination is light-tight to allow the use of an oscilloscope camera. The equipment permits the application of sawtooth or step voltage and current waveforms to the transistor electrodes, together with continuously variable d.c. voltages up to 150V for collectors and emitters and d.c. currents up to 60mA for collector and emitter and 6mA base, with appropriate polarities. Six 3½in scale meters with knife-edge pointers and mirror scales are provided for displaying d.c. currents and voltages. Base voltages are metered by a valve voltmeter to avoid loading the base circuit. All other meters are connected



Self-contained transistor curve tracer incorporating power supplies and display facilities in a cabinet 4ft 7in high by 2ft 2in wide by 2ft deep

directly to the transistor electrodes. Power supplies generated in the instrument are stabilised for mains voltage variations of ±10 per cent.

The cathode-ray tube has its own e.h.t. and heater supplies and display amplifiers. The "Perspex" measuring graticule is of 1cm squares. Horizontal and vertical datum lines are coincidentally engraved on both faces for freedom from parallax.

In a typical application of the equipment, such as displaying the curves relating collector current to base current, the base selector is set to the sawtooth position and the base range is chosen according to the characteristics of the transistor under test. The collector is switched to stepped negative voltage waveform, in which condition five values are obtainable. The curves displayed are then a direct representation of the current amplification, α', since $\alpha' = dI_c/dI_b$. If the collector current/emitter current ratio (α) for grounded base operation is desired, the same procedure may be followed and α calculated from the equation $\alpha = \alpha'/1+\alpha'$.

The voltage ranges provided by the instrument are greater than required by present transistors in order to cover future development. Current ratings cover transistors in medium power output stages. The instrument is constructed on the unit principle so as to allow easy withdrawal of units for servicing after releasing plug and cable connections.

New Post Office Radio Station at Ilfracombe

ILFRACOMBE Radio, the new Post Office Coast Radio Station at Mulacott Cross, North Devon, was opened for traffic on January 29. For the past three years the short-range radio-telephone service for these waters has been operated from a temporary station at Ilfracombe Head Post Office. This service, as well as the short-range radio telegraph service previously given through Burnham Radio, has now been taken over by Ilfracombe Radio.

Two Post Office Type W5 transmitters, designed and built by the Post Office engineering staff, are installed in the transmitting room and remotely controlled from the operating console n the operating room, where three Marconi " Mercury " receivers are provided in the main console for main watch-keeping and traffic handling. A Plessey 2182 kc/s receiver mounted in the auxiliary apparatus room is connected to loudspeakers in the main R/T and reserve operating consoles ; and a Redifon 500 kc/s receiver installed in the same room feeds a loudspeaker in the main W/T operating room. An R/T automatic alarm of Post Office design is connected to the Plessey receiver referred to above and responds to the special alarm signal which can be sent by ships in distress and requiring assistance. R/T terminal equipment for establishing connection with telephone landlines is of Post Office design.

Of the three operating consoles in the operating room, one accommodates the Marconi " Mercury " receivers and is fitted with control equipment for the transmitters ; the second is intended for use as the main W/T and R/T operating position ; and the third is in reserve. Both the latter are fitted with controls for the R/T terminal equipment. A standby diesel-generator set in the engine-room is able to take over the whole of the station load.

Large Industrial Mobile Vacuum Cleaning Plant

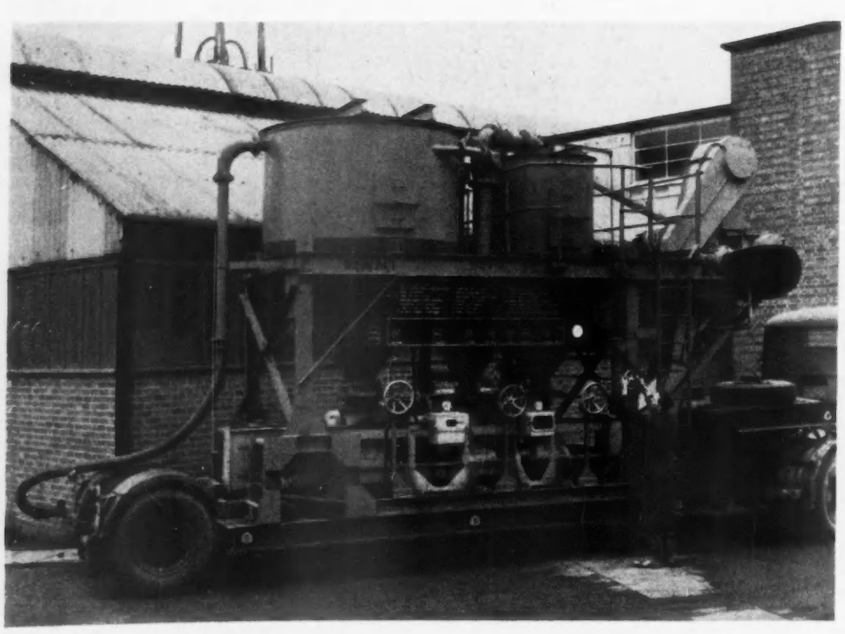
To eliminate the costs involved in installing permanent equipment which is only used periodically for the cleaning and removal of flue dust and grit in boiler plants a large mobile vacuum cleaning plant has been built by the British Vacuum Cleaner and Engineering Company, Ltd., Leatherhead, Surrey, for the National Coal Board. This plant now serves a group of collieries in the Midlands and is taken to any colliery as and when required. It is stated that, taking all cost factors into account, colliery officials have estimated that the plant will show a very considerable saving in boiler cleaning costs compared with normal permanent installations. The new plant, which weighs about 14 tons, can be seen in the illustration below and is generally similar to one supplied some two years ago to Dorman Long (Steel), Ltd., for furnace cleaning purposes. It is designed to remove dust at a rate of about 4 tons per hour, and all that is required on site is to connect the plant to mains power and water supplies.

As can be seen in the illustration, the equipment is mounted on a framework on the rigid steel chassis of an articulated vehicle. It includes a primary collector, twin cyclones and an air filter, with a multi-stage turbo-air exhauster. This exhauster has a maximum capacity of 1000 cubic feet per minute at 10½in Hg, and is driven through a David Brown helical speed-increasing gearbox by a 25 h.p. motor.

Dust-laden air drawn into the plant first passes into the 7ft diameter, 3 tons capacity separation unit, in which the heavier grit is deposited. The air then passes through two cyclones arranged in parallel, where the finer particles of dirt are removed, and any remaining dust is removed in a 4ft diameter filtration unit fitted with twelve 8in diameter sleeves. At the end of a cleaning period the turbo-exhauster is stopped and discharge valves at the bottoms of the various units are opened. The dust and dirt gravitate down through these valves into an enclosed Redler scraper conveyor set along the length of the chassis. At the end of the chassis this conveyor is extended up to form an elevator which deposits the dust into a conditioner. In this conditioner a series of nozzles spray water on to the dust and rotating paddles thoroughly mix the dust and water before discharge out to the side of the plant for disposal. The conveyor/elevator is driven by a 3 h.p. geared motor and the conditioner shaft by a 10 h.p. motor.

The equipment is connected to the required part of the boiler plant by a 4in bore flexible metallic pipeline, and from this point there is taken a 3in flexible hoseline to the places from which dirt has to be removed. Smaller bore equipment can be used if required for surface cleaning in boiler-houses or in coal screening plant buildings.

We are informed that two mobile equipments of similar design, which are now under construction for the Steel Company of Wales, are being fitted with rotary valves. With these valves in use it will be possible to keep the equipment in constant operation, the dirt being continually removed by the conveyor system below the units.



Mobile vacuum cleaning plant for colliery boiler equipment

Fuel Additives

A SERIES of data sheets is now available from the Amber Chemical Company, Ltd., 11a, Albemarle Street, London, W.1, summarising the properties of the combustion additives and liquid fuel improvers introduced during last year. These additives fall into three main series : Series 100 are powder additives, " 113 " being used in residual fuel oil and " 115 " with coal and pulverised fuel. Series 200 comprises " 224," a modified version of " 113," which, under certain conditions, can greatly reduce the cost of treatment. Series 500 are liquid fuel improvers ; " 509 " is used with residual fuel oil, " 511 " and " 515 " with residual fuel oil, coal tar fuel (creosote pitch) and bunker fuel, and " 513 " with diesel and gas oils. The functions of these additives are presented in the accompanying table.

Function	SSR " 113 " " 115 " " 224 "	SSR " 509 "	SSR " 511 "	SSR " 513 "	SSR " 515 "
Indication					
Air pollution	×	×			
Corrosive stack emission	×	×			
Sulphur corrosion ...	×	×	×	×	×
Low CO_2 recordings		×			
Sludge in fuel tanks and lines		×	×	×	×
Carbon deposits, needle seizure, exhaust emission, smoking				×	
Soot and carbon deposits on heating surfaces	×	×	×	×	×

Simplified Code for Computer Problems

A DEMONSTRATION was given last week at the London Computer Centre, 21, Portland Place London, W.1, of Ferranti, Ltd., of a new code which has been devised to simplify the putting of many problems into a form in which they can be solved by the company's " Pegasus " computer. This is known as the " Pegasus Autocode," and experience has shown already that its principles can be mastered in twenty-four hours, enabling users to submit instructions in typewritten form which can be put at once on to punched tape and scanned. Simplification of the method of presenting the problem has necessitated the preliminary insertion of additional instructions so that the computer can interpret the " Autocode," and this occupies a little more space in the store, but even so, the capacity is adequate for a great range of day-to-day calculations which can be handled with advantage by a computer, but which, in the absence of the " Autocode," might be the subject of laborious office work.

As an example of how the code is written, it was shown as applied to a quadratic equation for solution by the computer. A user accustomed to the code could write the programme in five minutes and it is claimed that a newcomer could write it in ten minutes. As a comparison, a full course in normal programming occupies two weeks.

Most " Autocode " instructions are written as equations, thus, $V5 = V1 \times V3$.

The above is an instruction to the computer to take the number out of part of the store identified as $V1$, also the number out of $V3$, multiply them together and put the result in $V5$. The next step might be $V6 = 4 \times V5$. This would indicate that the product just placed in $V5$ is to be multiplied four times and the product stored as $V6$, by which code it will be identified when further work has to be done on it, for example, $V7 = \text{SQRT}V6$ (i.e. take the square root of the number in $V6$ and place in $V7$).

The " Autocode " demonstration formed part of an afternoon lecture course at the Computer Centre, where some half-dozen similar combined lectures and demonstrations have been held previously. On this occasion the " Pegasus " computer was seen at work solving various problems chosen to illustrate the theme " what

can a computer do for the engineer ?" Answers to thirty simultaneous linear equations were printed out in four minutes, a task which would have taken about a fortnight to solve by ordinary methods in normal working days. Other demonstrations illustrated the computing of stresses in pipe systems, a single-plane structural frame programme (Livesley method), and the calculation of the fundamental properties of beams of varying section. An opportunity was given for examining the interior of the "Pegasus" computer, which contains 444 "packages" (electronic chassis) with plug and socket connections enabling any one to be removed and replaced by a spare unit while being serviced. The centre is equipped with magnetic tape mechanisms which may be coupled to a standard "Pegasus" computer via a tape control unit and have the effect of providing virtually unlimited storage capacity for exceptionally large calculations and data processing.

Side Loader Transporters

To show the high degree of manœuvrability, speed and handling capacity of a "Lancer" side loader under typical working conditions, Lancers Machinery, Ltd., 41, Knightsbridge, London, S.W.1, recently organised a demonstration of one its 4-ton machines in the yard of a large London timber merchant. These machines are now being made in three models of generally similar construction and having capacities of 3, 4 and 5 tons. Their overall width of 6ft 3in enables the machines to work with ease in aisles and gangways 7ft 6in wide, and with a wheelbase of 7ft 9in, they have a turning radius of 13ft 6in.

The welded steel plate chassis is designed to impart a high degree of rigidity, but to prevent the unavoidable stresses imparted on the frame in normal heavy working being transmitted to the engine and transmission, the main drive is arranged in three separate units connected by flexible couplings and shafts. These units comprise the engine, clutch and gearbox ; the final drive between the engine and back axle ; and the back axle assembly. The Ford engine used on the machine develops 42 b.h.p. at 1600 r.p.m., and drives through a four-speed gearbox giving road speeds from 4 to 27 m.p.h. If required, a two-stage Brockhouse torque converter can be fitted giving speeds of 0–10 and 6–25 m.p.h. A heavy duty duplex chain in the final drive box transmits the drive from the engine level to the back axle fitted with fully floating half-shafts. No springing is fitted on the rear axle, but the front axle beam on which stub axles are mounted is fitted with a torsional rubber suspension of special design.

The moving inner section of the mast assembly, which carries the forks, is fully supported on the fixed lower section through sealed ball bearings, and is raised by a large hydraulic cylinder at speeds up to 65ft per minute. Its lowering is effected through gravity at speeds which are under full hydraulic control. The mast assembly is moved sideways along its transverse track on the chassis by a pair of heavy duty chains. A double-acting hydraulic cylinder is used to drive the traversing shaft on which the chain driving sprockets are keyed, and the traverse time is adjustable from two to ten seconds. This arrangement of a dual drive from a single cylinder, it is stated, ensures alignment of the forks and prevents slewing of a long load as it is raised. At the limit of the fork assembly traverse in either direction the cushioning effect imparted through the hydraulic cylinder prevents undue jolting of a load suspended on the forks. Before a heavy load is raised or lowered with the mast in its extended position a pair of hydraulic jacks fitted at each corner of the mast gap in the chassis can be lowered to stabilise the machine.

For these machines the makers have adopted a relatively low-pressure, large volume, hydraulic system rather than a high pressure system which would have allowed the use of smaller diameter cylinders. With this low pressure system using fluid at about 1000 lb per square inch, it is claimed that valves, seals and hydraulic lines are subjected to far less wear and stress in service than would be the case if high pressures were used. All of the hydraulic equipment is of Hamworthy design and manufacture, and the cylinders throughout the machine are fitted with hard wearing chromium-plated pistons.

In the course of the demonstration with the side loader in the timber yard it was shown handling various kinds of loads from sawn planks to heavy logs in the aisles of the storage areas and in the gangways of the woodworking machine shops of the yard. The machine used for the demonstration can be seen in the photograph we reproduce on the left.

Side loader with fork assembly extended to the operative position for picking up or depositing a load

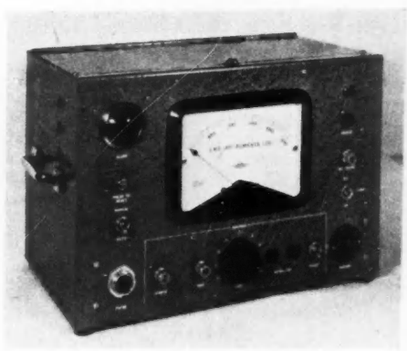
Tube Tester for Non-Magnetic Metals

A TESTER for locating faults or corrosion in tubes by detecting changes in the characteristics of search coils carrying high-frequency current has been introduced by C.N.S. Instruments, Ltd., 61, Holmes Road, London, N.W.5. In the present version, the h.f. currents are generated by valve circuits. When seeking faults in tubes of non-ferrous metal or stainless steel, the probe or probes containing the search coils are passed around or through the tube specimen. The instrument is first balanced to give a zero meter reading when the probes are in a good specimen of the material, or in a known good section of the tube under test. Cracks, inclusions, superficial faults or changes in wall thickness disturb the balance attained by adjustment of resistive and inductive variables inside the main unit and cause deflection of the meter needle accompanied by a warning light and a buzzer alarm. With a high-speed alarm relay, testing can proceed at 100ft per minute. A panel switch can be set so that the audible alarm either stops automatically or continues to sound until turned off manually.

The alarm system is adjustable in sensitivity so that the user may by judicious use of the setting pass over very small faults which would not impair the function of the tube and reject only where the faults are of significant size. In practice it has been found that cracks equal in size to 5 per cent of the tube wall thickness are easily detectable and a 2½ per cent step in wall thickness gives a pronounced signal.

When the equipment is used for checking for corrosion in condenser tubes, the probe is first set to balance in a known good specimen of the original material. Upon probing the condenser tubes any corrosion will produce an out-of-balance effect and sound the alarm. The existence of a known standard specimen is necessary where corrosion may be equal in extent throughout the length of the tube.

Normally, the equipment operates at 4·7 kc/s and this frequency covers a very wide range of materials. It can also be supplied to operate on four frequencies (1, 4·7, 12 and 20 kc/s), to suit materials of different resistivity and permeability, in which case a frequency selector switch is provided at the back of the unit. This facility may also be useful with tubes of exceptional wall thickness to achieve full penetration. Where material is particularly thick walled and of low resistivity and permeability, probing is desirable both from the inside and the outside.



The tube tester illustrated weighs under 20 lb

The instrument measures 1ft 2in by 10in by 10in. A tapped input transformer enables it to be used on all normal mains voltages.

Small Oily Water Separator

A NOTE received recently from Hopkinsons, Ltd., of Huddersfield, points out that oily water separators of sufficient capacity for handling medium and large tonnages have been made for several years, whilst only a restricted range of equipment is available to meet the needs of small vessels which come within the scope of the Oil in Navigable Waters Act of 1956. In response to a request for such a separator to handle oily water from bilge and ballast tanks and to be not much larger than a 40-gallon drum the firm has now produced small separators in two sizes. One of these separators is of 40-gallon drum size and is capable of treating about ½ ton of oily water per hour, and the larger size can handle some 2–2½ tons per hour.

Each of the two sizes of these separators consists of a mild steel cylinder fitted with water and oil outlet connections in the centre of the bottom and top covers respectively. Within the cylinder hollow centre pieces with ports cut in their sides extend from the two outlets and a tube down the centre of the cylinder is slidable over these centre pieces. This central tube acts as a valve and its length is such that in its upper or lower positions only the ports in the top or those in the bottom centre pieces are opened at any one time. A float fixed on the tube is so loaded that when fully immersed in water it will rise—thus opening the bottom ports to the water outlet. When surrounded by oil the float sinks—thus opening the oil outlet ports and shutting off the water outlet ports.

A baffle in the separator gives an initial upward velocity to any oil particles, and maintains in the cylinder a comparatively stagnant volume of liquid in which the natural tendency of oil globules to rise to the top is encouraged. A coarse sieve is fitted to restrict the passage of any particles likely to bind the slide valve used for controlling the oil and water flow.

The action of the separator is entirely automatic, the opening of the oil and water ports being governed by the condition of the oily water fed through the separator, e.g. if the water content is very high, then the water outlet remains open until sufficient oil has collected to depress the float, when the water flow is automatically cut off. When the oil content is high, the oil outlet remains open until sufficient water has collected to lift the float, opening the water outlet and automatically shutting off the oil outlet. Although normally employed where gas (fuel) and lubricating oil may be the subjects of separation, the addition of a small electric heater or steam coil in the top of the separator enables it to be used on residual fuel oil of 0·95 (at 60 deg. Fah.) specific gravity.

High Precision Cylindrical Grinding Machine

WHEN A. A. Jones and Shipman, Ltd., of Leicester, opened new showrooms at 50–52, Great Peter Street, London, S.W.1, recently, there was shown for the first time a new high precision cylindrical grinding machine of 5in by 12in capacity. This machine incorporates a new form of control by which feed increments of 0·000005in can be made, and it is claimed that using dead centres the roundness achieved on work is within less than 0·00001in, and with standard workhead live centres 0·000025in.

High-precision 5in by 12in capacity cylindrical grinding machine

The solid cast iron bed of the machine is supported at four points on a welded steel base and the upper portion of the bed which carries the main slideways also supports the back slide. The slideways are all finished to a high degree of precision, and are lubricated by rollers contained in interconnected oil wells. In the wheelhead assembly the side members are designed to envelop the back slide to add stiffness to the structure and protect the slideways. The slideways themselves are completely submerged in an oil bath, which is of sufficient depth to maintain a level of oil over the wheelhead feedscrew, the gearing of the feedshaft to the feedscrew and the feed handwheel bearing. A balance weight is provided to keep the wheelhead feed nut in close contact with the feed screw.

The grinding wheel spindle is driven by a flat belt from a 1½ h.p. motor and through interchangeable pulleys has two speeds of 2240 and 2500 r.p.m. This "Nitralloy" spindle runs in lead bronze bearings which are designed to allow automatic adjustment of bearing pressures for different spindle speeds by variation of spindle running temperature. The spindle, therefore, regulates its own bearing pressures and maintains a constant degree of bearing tightness.

The table has a maximum travel of 13½in and its traversing system has coarse and fine movement rates which are selected by a thumb lever. Through the cross feed handwheel the wheelhead has a total travel of 3in and this handwheel is coupled through one gear only to the cross feed screw. It carries a graduated dead stop which can be arranged to contact a fixed stop in the bed structure. The position of this dead stop in respect to the handwheel can be adjusted by a worm and wheel device to enable the fine regulation of feed increments with reference to graduations showing 0·00001in reduction on diameter. When necessary for purposes of rapid adjustment of position of the dead stop relative to the cross feed shaft, the fine feed worm can be withdrawn from engagement with its mating worm wheel by the pulling out of the handle of the cross feed handwheel.

The workhead, which has a fixed base, is provided with live spindle facilities in addition to the normal dead centre arrangements. For live spindle working chucks, faceplate, &c., which register on a long internal cone seating in the workhead spindle can be readily interchanged. A ⅓ h.p. motor which drives the workhead spindle through two-step pulleys has six speeds, an arrangement which gives six speeds from 75 to 375 r.p.m. in a low range, and six speeds from 150 to 750 r.p.m. in a high range.

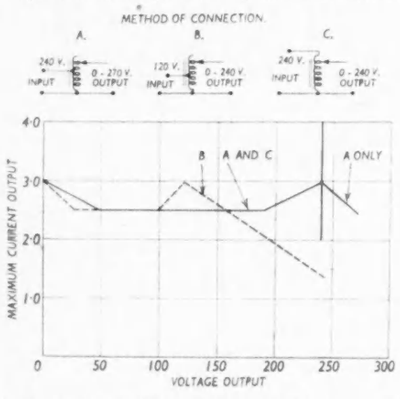
Coolant is supplied from a tank in the base of the machine by a 4 g.p.m. pump and the return coolant passes through a series of settling trays before it passes back into the main tank. If required a paper roll coolant clarifier can be supplied for the machine. An internal grinding attachment which can also be supplied if required is available with two sizes of spindle, one for holes from ⅜in to ⅝in diameter and the other for holes from ⅝in to 2in diameter. This attachment is fitted on a bracket bolted to the front of the wheelhead and is driven through belts and a countershaft from the main motor.

In addition to this machine the firm has installed a number of its other designs of precision grinding machines in the new showrooms for demonstration purposes, and some of these machines are fitted with well-known autosizing and wheel forming devices.

Toroidal Voltage Regulators

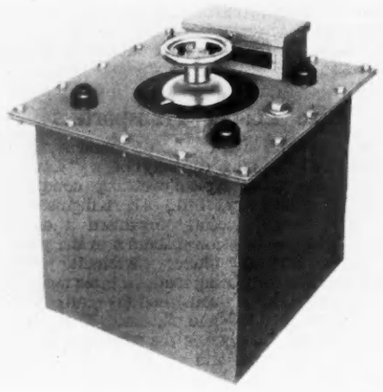
FOUR new single-phase voltage regulators with toroidal auto-transformer windings are being introduced by Foster Transformers, Ltd., South Wimbledon, London, S.W.19. The basic sizes are known as "Troidac" 2·5, 10, 20 and 40. Of these, sizes 2·5, 20 and 40 are in production, and the "Troidac" 10 unit will be available shortly.

All units are supplied for nominal ratios of 240/0–270V or 240/0–240V by means of alternative input connections as shown in the diagram, which also indicates the ratings of the 2·5 transformer for alternative outputs and when using the centre tap as a 120V input connection. Windings are tapped additionally at approximately 25 per cent. The tappings may be used with auxiliary transformers as in buck-and-boost schemes.



Methods of connection and corresponding outputs of the "Troidac" 2·5 regulator

In the 2·5 voltage regulator the core, winding (apart from the brush track), the bearing for the carbon brush gear and the terminals are encapsulated in a black polyester resin. This provides a rigid assembly and affords maximum protection to the winding. In this form the regulator is designed for back-of-board mounting. Three fixing bushes are moulded into the unit. The spindle length allows for panel thicknesses up to ¼in. An alternative is the enclosed unit for portable or bench top use, in which three rubber feet are provided on covers moulded in black polyester resin, enclosing the brush gear of the basic regulator. The terminals are protected by a moulded "Bakelite" cover provided with knockouts and designed to accommodate extra fittings if required, such as glass cartridge fuses, external secondary terminals, and primary switch.



The "Troidac" 40 oil-cooled regulator

The "Troidac" 10 will also be a resin-cast unit. Of the other two regulators in the range the "Troidac" 20 is air cooled and the "Troidac" 40 (illustrated) is oil cooled. This regulator is rated at 40A from 0V to 240V and 35A from 240V to 270V. A single unit will provide approximately 9·5kVA of control and a three-gang version can be provided. Track and brush gear are under oil, enabling the regulator to be used in adverse atmospheric conditions.

"Mallory" 1000

IT is announced by Johnson Matthey and Co., Ltd., of 73–83, Hatton Garden, London, E.C.1, that the firm is now producing and marketing "Mallory" 1000, a machinable high-density material composed of tungsten, nickel and copper and made by a special powder metallurgy technique. "Mallory" 1000 has a uniform structure, high strength and great density. As the material may be subjected to all normal machining and grinding processes, it is suitable for the manufacture of components where high mass coupled with high strength and small volume are important considerations. Components fabricated from "Mallory" 1000 are suitable, the firm says, as counterbalances for aircraft control surfaces, balances for flywheels, inertia members in such instruments as accelerometers, and as rotating inertia members, where strong precision-machined rotors are required in a limited space. A further application of "Mallory" 1000 is in radiation shielding. By virtue of its physical structure and its very high density, "Mallory" 1000 effectively absorbs gamma-rays and can also be used for the shielding of neutron-emitting fission by-products, provided that the intensity of bombardment is relatively low. Such low-intensity neutron bombardment causes only moderate activity in "Mallory" 1000. The material is supplied in special pressed shapes as well as in the form of round and rectangular bars.

Industrial and Labour Notes

Economic Outlook

The Chancellor of the Exchequer, Mr. Heathcoat Amory, presided at a meeting of the National Production Advisory Council last Friday. In a review of the economic situation, he spoke about "small but distinct" signs of an improvement. The Chancellor said there were signs that the index of production was now edging up; how fast production could be safely increased at home depended to a large extent on how far exports could be increased. This country would benefit from growing world trade if costs were kept competitive.

Actually, the Chancellor went on to say, the upward creep of costs continued in 1958, with wage rates rising and productivity static. In the first nine months of last year, labour costs for each unit of output were something like 6 per cent up on the comparable period of 1957, due partly to higher wage rates and partly to a fall in output. Certainly, the Chancellor added, there were offsetting falls in import costs which helped to keep prices steady. But, the Chancellor remarked, import prices could not be counted on to fall any further, nor would it be to this country's long-term advantage that they should. The steep decline ended some months ago and with industrial production recovering in the U.S.A. and elsewhere, world commodity prices might well start moving against this country and probably were already doing so on balance.

Taking everything into consideration, the Chancellor said, this year had started on a sound basis for the safe resumption of expansion. A steady rising trend in national output from now on would make fuller use of resources and so help to keep costs down. There was no doubt that higher productivity could contribute a lot to the first phase of an expanding national output. But, he urged, the objective of keeping costs as a whole steady must be an agreed policy on the part of everybody, Government and industry, employers and unions. It was fundamentally important at a time when export business was going to be far more competitive than in any period since the war.

Fuel and Power Policy

Last Friday, the House of Commons discussed a private member's motion calling upon the Government "to frame as a matter of urgency a policy for the fuel and power industries of this country to secure a proper balance in the use of imported and indigenous fuel and the effective co-ordination of the three nationalised fuel industries." This motion was proposed by Mr. Blyton who urged, in the course of his speech, that priority should be given to the use of coal in the production of gas and electricity. He argued that this country's fuel policy must be based upon its own vast resources of coal and framed to ensure that, where coal was the natural and economic fuel to be used, it ought to be used. The aim must be, Mr. Blyton asserted, to give coal its rightful place in the economy.

Speaking for the Government, the Parliamentary Secretary to the Ministry of Power, Sir Ian Horobin, suggested that the real issue at the back of the motion was "an appeal to hinder oil and to encourage coal." He felt bound to point out, however, that oil represented a great industry that British initiative and enterprise had developed. The history of the last ten years as far as Europe and this country had been concerned, Sir Ian continued, had been of oil coming to the rescue of a shortage of coal. Sir Ian went on to remark that the Government had been pressed on a number of occasions to alter the conditions under which certain power stations burned oil. As a result of discussions which had been taking place, he said, the oil companies, the Central Electricity Generating Board and the National Coal Board were considering together whether it was practicable within the framework of existing contracts to postpone the conversion of two more power stations during 1959 as a gesture by the oil companies to the coal industry in its present difficulties. If that was found practicable, the Generating Board would require "a very considerable additional quantity of coal" this year, which would be of great assistance to the coal industry. Sir Ian ended his speech by expressing the Government's belief that the consumer should have the choice (of fuel). The consumer, he said, was the only person who could really know in each individual case what was best for his actual problem and for his workpeople whose jobs were threatened if a competitor abroad could get a more suitable fuel.

Industrial Building

The Board of Trade has stated that in the last quarter of 1958, industrial development certificates were issued for a total area of 11,200,000 square feet of industrial building in Great Britain. The total for the whole of the year, amounting to 46,100,000 square feet, was about 28 per cent below the 1957 total.

It is estimated that, in the second quarter of last year, building started on 480 schemes aggregating 12,010,000 square feet, which was an area much higher than in any quarter of the preceding eighteen months. The area estimated to have been completed in the same period, 12,080,000 square feet (470 schemes), was slightly below that for the two preceding quarters. The area of schemes completed in the first six months of 1958 was approximately 8 per cent less than in the comparable period of 1957.

"Public Accountability"

In concluding his chairman's address at the annual meeting, last Friday, of Colvilles, Ltd., Sir Andrew McCance commented on the uncertainty which the threat of renationalisation had brought into the future prospects of the steel industry. Evidence of that uncertainty, he said, could be seen in the present state of trade.

In the arguments put forward originally to justify the policy of nationalisation, Sir Andrew observed, it was always tacitly assumed that the profits being made under private ownership would continue after the industries became state controlled. The records of the nationalised industries for the past ten years, during which time private enterprise industries were moving from success to success, had shown how completely fallacious that argument had proved. The truth must be faced that under public ownership, heavy losses, more often than not, had made former profits disappear. Industries which formerly made substantial contributions, by way of income tax, to the national income now made no contribution at all. That loss of revenue, Sir Andrew remarked, was made good by larger tax contributions from the rest of the population, including the wage-earners themselves.

Sir Andrew went on to say that, in the search for arguments to support nationalisation policies, frequent reference was made to "public accountability," a phrase of rather nebulous meaning. If those directing the affairs of a company whose shares were held by individual investors failed to conduct the business of the company efficiently, the shareholders had direct and immediate channels of redress. The same thing could certainly not be said of the nationalised industries! It had become abundantly clear, Sir Andrew asserted, that nationalisation did nothing to enforce public accountability on those industries which it took over; it merely allowed them to escape public accountability in the ordinary meaning of the term.

Development Areas

During a debate in Parliament on Tuesday on supplementary civil estimates, the Parliamentary Secretary to the Board of Trade, Mr. John Rodgers, said that in the last two months sixty-three extensions to Government factories had been authorised in the development areas. These would cost just over £2,000,000 and would provide over 750,000 square feet of factory space. The geographical distribution of the extensions and the number of jobs they would provide, Mr. Rodgers pointed out, was: in the north-east development area, twenty-eight extensions to provide jobs for 2580 people; in the notth-west, two extensions, providing jobs for 160; in Wales, twenty-four extensions to provide jobs for 1090 people, and in Scotland, nine extensions, providing jobs for 680 people.

Mr. Rodgers went on to say that the Board of Trade's policy was to let factories in the development areas at current market value rentals which were assessed by the district valuer. But, he added, there were two categories which gave rise to difficulties, and the Board was prepared to allow temporary abatements of the current market value rents to meet those difficulties. First, on leases expiring before January 31, 1960, which would be renewed at generally higher rents, the increases to sitting tenants would be spread over a five-year period, so that the new rent would not be paid in full until the sixth year of the new lease. That, it was felt, would give tenants a breathing space in which to adjust themselves to having to pay the higher rents. Secondly, Mr. Rodgers, continued, to encourage firms to take up quickly those factories which were or might become vacant, the Board was prepared, during the next twelve months, to allow successful applicants for such factories a flat abatement of 25 per cent on the current market value rent for a period of five years.

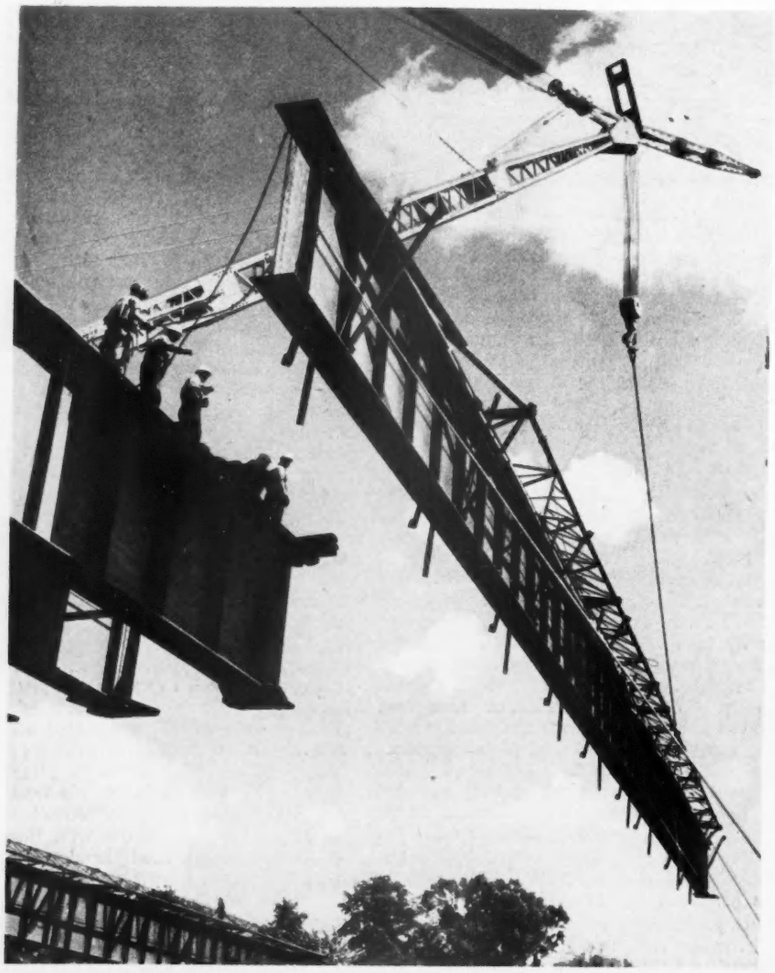
Riviere des Prairies Bridge, Quebec

An unusual feat in bridge erection was recently completed during the building of a bridge spanning the Riviere des Prairies, north of Montreal. In this work ten 225ft girders, twenty of 212ft and ten of 120ft, were lifted into position with a "single rig." The larger girders weighed 66 tons each and were 9ft 6in deep.

The bridge consists of ten parallel deck plate girders continuous over four spans of 176ft, 212ft, 212ft and 176ft. These spans, together with the approach spans, which are also ten parallel deck plate girders with single and three-span continuous spans, give the bridge a total length of 1714ft. The width of the bridge is 92ft, including two 36ft wide carriageways, a central strip 10ft wide, and a 5ft wide maintenance "sidewalk" on each side.

In the erection of the big girders, a 6-ton tubular truss was attached to the top flanges of the girders to provide lateral stiffness during hoisting operations. This special erection truss is shown in the illustration on the RIGHT, where a 225ft girder is being hoisted into position. The "single rig" was a nominal 70-ton capacity stiff leg derrick "traveller" with a 135ft long boom. The first girders of 225ft were erected spanning from the abutment to the first pier, beyond which they cantilevered 50ft. When this set was completely erected, the traveller was moved forwards on to the cantilever section and the second set of girders, 212ft, were erected, splicing to the cantilever end of the first set, resting on the second pier and, in turn, cantilevering 50ft beyond this pier. The third and fourth spans were erected in a similar manner. The pier contractor's trestle alongside the bridge proved very useful in feeding steel out to the traveller. The main advantage of erecting in this way was the elimination of falsework.

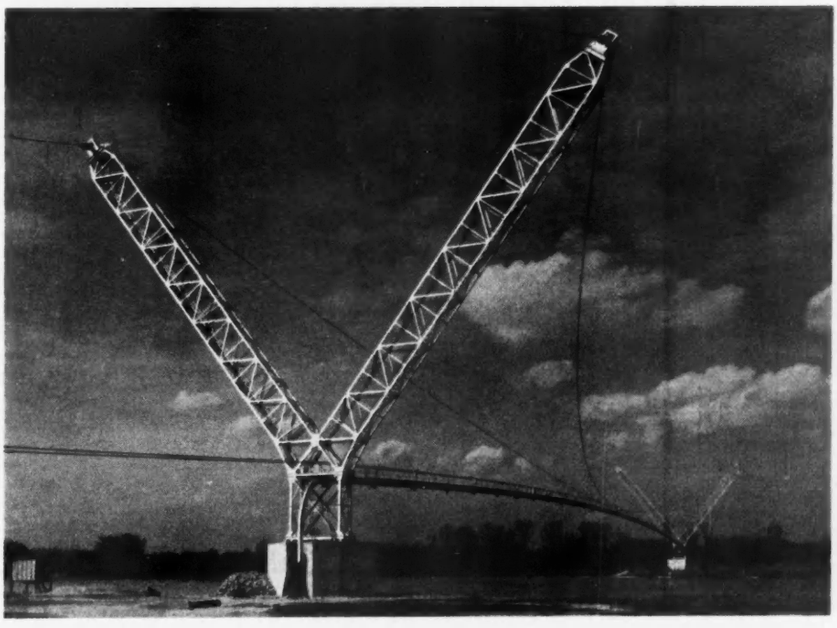
The bridge is part of the new expressway from Montreal to the Laurentian mountains (which start about 45 miles north of Montreal), which is expected to be completed and opened to traffic later this year. The LOWER view shows the bridge nearing completion. The steel spans were built by the Dominion Bridge Company, Ltd.



Suspension Pipe Bridge Over the Danube

THE main natural gas wells exploited by the Osterreichische Minerölverwaltung A.G. are in the north-easterly part of Lower Austria. In order to supply industrial undertakings in the Vienna region and south of the capital, a pipeline has been laid from the districts of Zwerndorf and Auersthal to the south, which had to be taken across the Danube near Mannswörth, in the neighbourhood of Schwechat airport. The diameter of the pipe in question was 400mm. A crossing under river was ruled out for technical reasons, quite apart from the very high cost. On the model of well-known American and Italian designs, the firm of Waagner-Biro A.G., Vienna and Graz, then developed the novel suspension bridge shown in our illustration.

With pipe bridges comprising only the pipe itself and a service catwalk, the vertical load is comparatively small in relation to the length of the span. The design must take into account the fact that wind loads and dead loads are of the same order of magnitude. In the present case it was decided to use a funicular suspension which had been developed by Waagner-Biro A.G. approximately ten years previously. As this was the first practical application it was considered expedient to carry out model tests in particular with regard to aerodynamic stability.



Suspension bridge of 320m span and total length 506m, carrying a 400mm diameter natural gas main over the Danube near Mannswörth

The support comprises four longitudinal main walls (two carrying cables and two tensioning cables), which are of armoured construction, together with a number of multi-strand, twisted suspension cables which connect the carrying cables and the catwalk. The two carrying cables are taken over the tops of Y-pylons situated at the supports of the span, while the two tensioning cables run along the bottom of the bridge immediately above the catwalk, and act as stiffeners. All four main cables are anchored on two terminal concrete blocks.

The span between the two pylons amounts to 320m, with outside rope spans of 93m each between the pylons and anchors, making the overall length equal to 506m. Between the centre of the arch and the tops of the pylons the carrying cables rise 35m (measured in the direction of the suspension cables). The rise of the stiffeners at the centre is 5m.

For the pylons, concrete foundations were erected with their top surface 1m above highest high water level. From that point the steel structures rise to a height of 38m. The distance between the tips of the booms is 48m, making the angle of the Y equal to 75 deg. A pitch of 10m was used for the suspension ropes. The pipe, which, as has been mentioned, has a diameter of 400mm, carries the gas at a pressure of 64 atmospheres gauge. The pipe is supported on rollers which are mounted on U-brackets ; the 0·6m wide catwalk is mounted on the same brackets, above the pipe, and equipped with removable gratings. The tops of the pylons, and the joints of the suspension wires with the main carrying cables, are connected by horizontal ropes in order to give a stiffer rope polygon.

Dead load along the main span amounts to approximately 400 kg per metre, live loads were calculated as a water filling of the pipes equivalent to 130 kg per metre, and the formation of ice corresponding to 56 kg per metre.

Wind loads were calculated on the basis of 165 kg of force per square metre, or corresponding to a hurricane of 185km per hour. This, therefore, covers the standard stagnation pressure of 110 kg per square metre. Because the bridge is situated near the edge of a region of seismic activity, a horizontal acceleration of $^1/_{200}g$ was additionally allowed for.

For the steelwork of the pylons, the catwalk and the anchor attachments, use was made of the structural steels St37S, St37T and St55S. The armoured carrier and tension ropes have a diameter of 62mm and consist of internal layers of round wires of a strength of 180 kg per square millimetre, and outer rows of wedge and Z-wires of an ultimate strength of 165 kg per square millimetre. The calculated ultimate strength of the carrier cables is 425 tonnes. Under catastrophic load conditions the carrier ropes may have to support up to 167 tonnes, so that there is a safety factor of 2·55.

Wind tunnel tests were carried out with a model of part of the bridge to a scale of 1 : 8·4. The model was supported as nearly as possible with the same constraint as the real structure. The tests showed that small improvements in the wind-exposed profiles rendered the bridge safe from flexural and torsional vibrations over the whole range of wind velocities.

The pylon foundations were carried out with walls of sheet piling and shaped so as to resist drift ice, with a safety factor of 7 against overturning in the direction of flow of the river. The shape of the anchor blocks was determined by the form of the steel trestles carrying the rope attachments. All steel parts are completely embedded in concrete. These blocks are capable of withstanding horizontal tensions in the cables of 470 tonnes, and vertical lifting forces of 115 tonnes.

The bridge was erected entirely without scaffolding and without utilising any of the required daylight under it. Shipping was stopped for ten hours only on each of four days. When the two pylons had been placed in position, the carrying cables were unrolled from drums placed on the left bank and passed over three auxiliary vessels. The cables were then raised to the tops of the pylons. In a similar manner, the tensioning cables were brought across the water and provisionally tightened. The correct position of the suspension and cross-bracing attachments, and of the steel parts of the catwalk, had been marked on the main cables in the works. For attaching the suspension clamps on the carrying cables, special inspection cars were used. Adjustment of the rope positions and tensions was made at the anchors, using hydraulic jacks with calibrated manometer gauges. Corrections for alignment of the bridge were carried out by means of turnbuckles in the suspension wires.

The novelty of the design is stated by the contracting firm to be characterised by the inclined funicular polygons, which meet along a common edge where the primary loads are attached, further, by the tensioning cables which meet with the carrying ropes in a common joint at the centre of the span, and, finally, by the Y-shaped pylons, the booms of which lie in the plane of the supporting polygons ; all these aspects of the design are stated to be the subject of Austrian and foreign patents.

International Study of Atomic Liability

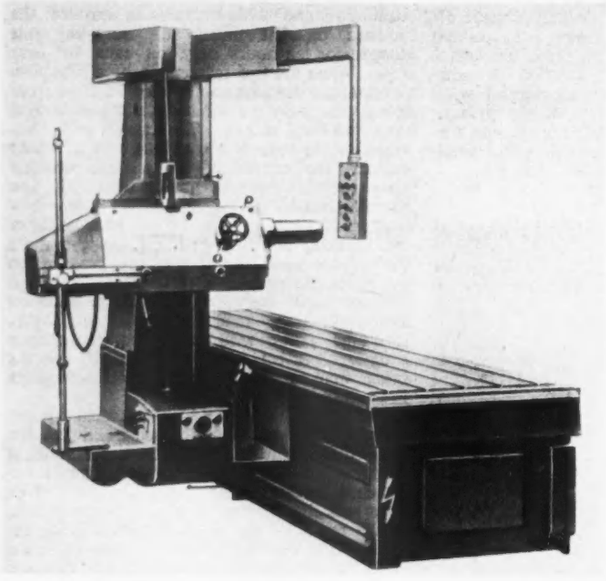
A panel composed of representatives of nine countries which are members of the International Atomic Energy Agency has been appointed to consider problems of third party liability and will study the steps necessary to solve the international problems involved. The question of third party liability is stated by I.A.E.A. to be of the utmost importance for the international development of atomic power. It is considered that the establishment of common standards for legal protection of victims of accidents which may involve radiation hazards should proceed in step with the establishment of technical standards for health and safety. Common standards of liability should be coupled with generally adopted minimum requirements for financial coverage of the risks involved. The present lack of adequate rules and accepted definitions of liability in the case of nuclear accidents constitutes a serious retarding factor in the growth of the atomic energy industry. This is true in national contexts but is still more serious in bilateral or truly international operations such as those carried out under the auspices of the International Atomic Energy Agency. The problem would grow even more complicated if national legislations started to adopt different solutions.

The initial programme of I.A.E.A. therefore stresses the need for efforts to establish international standards and definitions of areas of responsibility which would do much to harmonise national practices which are now being formulated in many countries.

The chairman of the panel, Dr. Paul Ruegger (Switzerland), is a well-known expert on international law and a member of the Permanent Court of Arbitration and of the Board of the Academy of International Law in The Hague.

Some Continental Machine Tools

A NUMBER of Continental machine tools of new and improved design were shown at an exhibition held recently at the showrooms of the Elgar Machine Tool Company, Ltd., 172–178, Victoria Road, Acton, London, W.3. One of these machines, which is illustrated below, was a new boring/milling machine made by Mecof of Ovada, Italy. This machine has a fixed table, available in four different lengths from 104in to 155in, with a working surface 38in wide. The table is mounted directly on the bed and the column on which the head saddle is vertically adjustable is arranged to traverse along slideways machined along the side of the bed. According to the length of the bed supplied the column traverse along the side of the table can be from 61in to 112in. The head, which has a vertical travel of 37½in on the column, can be swivelled up to 45 deg. in both directions on its saddle. The column can be traversed along the bed, and the head on the column, at twelve feed speeds from 1·6in to 54·5in per minute.



Mecof boring milling machine with fixed table and traversing column

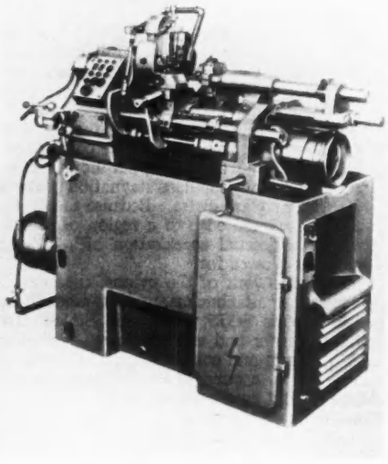
The quill mounted spindle is driven by a flange mounted 6 h.p. motor and has nine speeds from 39 to 1132 r.p.m. It has a travel of 25·6in and the six rates of feed are from 0·0015in to 0·11in per revolution. An angle milling attachment can be mounted on the spindle if required, and there is also available an overarm which can be fitted between the head and a support column fixed on the open side of the table to provide a tailstock support for the spindle.

An open-side planing machine now being made by Ezio Pensotti of Italy, in four sizes with planing lengths from 2000mm to 8000mm, is now available with a milling head which can be fitted on one of the two cross slide tool box saddles. These milling heads are complete with motor drive, one model having twelve spindle speeds from 40 to 710 r.p.m., and the other eighteen speeds from 26 to 645 r.p.m. The cross slide has sufficient overhang on the open side of the machine and on the column for either the tool box saddle or the milling head saddle to be traversed clear of the table whilst the other saddle is in use. A vertical grinding attachment is also made for fitting on to a tool box saddle of the machine.

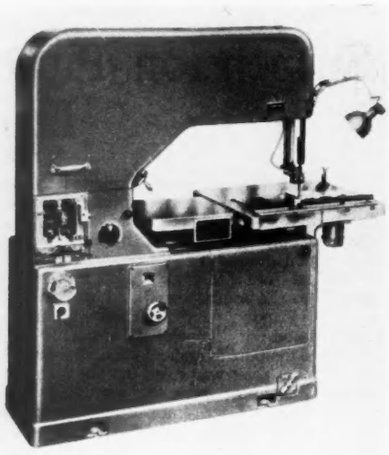
The machines of German manufacture handled by the Elgar Machine Tool Company, Ltd., include the Traub single-spindle automatic chucking machine shown in another of our illustrations. This machine has a bar bed of simple, stiff construction designed to give a long accurate working life. Its two cross slides are actuated by cams mounted on splined shafts below the bed bars, and a tailstock tool is moved in respect to the work by a large scroll cam. The camshafts are driven through gearing by an independent motor and the tool operating cycle is independent of the main spindle drive. This machine, which swings work up to 110mm diameter and 140mm long, has twelve spindle speeds from 200 to 2500 r.p.m. It can be fitted with either a manual or an air operated or a hydraulically-operated chuck. An overarm mounted slide on the headstock is operated from the front camshaft by a lever mechanism.

The Mössner "Rekord" heavy duty universal band sawing machine, as can be seen from the accompanying illustration, has a particularly deep throat of 37in, which facilitates the machining of large workpieces. It has an infinitely variable band speed range from 50ft to 3000ft per minute for band filing, band grinding or sawing, whilst a special high speed of 7700ft per minute makes it suitable also for fusion cutting purposes. The roller guide table fitted has a surface of just over 31in by 29in, and to provide a further support for large workpieces there is an additional table at the rear which is about 18in square. A power feed to the roller table has a movement of 18in and the feed pressure is adjustable to suit the class of work being handled.

The blade drive is from a 5½ h.p. motor and the blade is carried over three rubber-faced aluminium wheels. In addition to a saw guide with carbide tipped inserts there is provided a roller guide for use when fusion cutting and working at high saw speeds.



Traub bar bed single-spindle chucking automatic



Mössner heavy duty band sawing machine

The other new machines shown at this exhibition included a Mannaioni "Man-au-Cycle" high-speed automatic screw-cutting machine for work up to 36in long by 13in diameter over the bed and 7in over the carriage, a Weisser "Frontor 35" semi-automatic turning machine; a Rambaudi milling machine with hydraulic copying equipment; and an Utita multi-chuck, ending, centring and boring machine.

Atomic Waste Disposal

The first series of meetings of the I.A.E.A. expert panel on the disposal of radioactive wastes took place in Vienna recently. The present study of problems connected with the disposal of radioactive wastes in the sea is being undertaken following a resolution by the United Nations Conference on the Law of the Sea on April 27, 1958. At the Second United Nations Conference on the Peaceful Uses of Atomic Energy in Geneva last September, opinions were also expressed that such a research was very desirable. The panel was established in October; members attending the first series of meetings came from Canada, Czechoslovakia, France, India, Japan, Netherlands, Sweden, the United Kingdom and the United States of America. The Food and Agriculture Organisation (F.A.O.), World Health Organisation (W.H.O.), and United Nations Educational, Scientific and Cultural Organisation (U.N.E.S.C.O.) were represented by observers.

The many complex problems associated with the disposal of radioactive wastes in the sea touch upon different aspects of nuclear energy developments in the world, including nuclear propulsion. The related problems concern, for instance, techniques of treating wastes, oceanography, marine biology, protection of fisheries and radio-biology. All these aspects must be considered in detail so as to ensure conformity with recognised health standards. The panel therefore decided to establish working parties which in co-operation with the I.A.E.A. staff will assemble information and analyse available data in these fields. They will also examine the need for additional research work.

The results of the working parties will be submitted to the full panel which hopes to complete its task in the course of 1959. The first report of the panel is expected to contain a series of recommendations founded both on a general survey of the whole field and on detailed studies of different aspects.

Interkama 1960

It is announced that the Second International Congress and Exhibition of Measuring, Control and Automation Equipment, "Interkama 1960," will be held in Düsseldorf during the period November 2 to 10, 1960. The organisation of this event is again in the hands of NOWEA Nordwestdeutsche Ausstellungs - Gesellschaft, Düsseldorf, Ehrenhof 4.

Cruise Liner S.S. "Santa Rosa"

BY OUR AMERICAN EDITOR

With the "Santa Rosa" and "Santa Paula" entering the New York–South America cruise service of the Grace Line last year, the American merchant fleet has obtained two major additions in the luxury liner class. The 20,000-ton vessels are propelled by 20,000 s.h.p., twin-screw turbines at a normal speed of 20 knots. They accommodate 300 passengers each, all of them in first class. The most remarkable design aspects of the ships are their exceptionally high deck-space-per-passenger ratio and an unusual cargo handling system employing a combination of conveyors and lifts.

THE recent entry into service of the S.S. "Santa Rosa" and her sister ship, S.S. "Santa Paula," is of particular significance to the American merchant navy, as there had not been a truly new passenger liner addition since the completion of the S.S. "United States" in 1952. The operation, design and construction of these two vessels brought together three of the most respected American firms in shipping, naval architecture and shipbuilding. The Grace Line, for more than a century, has pioneered and served commerce between the Americas, and the two new 20,000-ton, 300-passenger liners are the main ships in its fleet-replacement programme. For Gibbs and Cox, Incorporated, the new liners represent its most significant design effort in the commercial field since it developed the S.S. "United States." It should be noted that this firm also developed the predecessors and namesakes of the "Santa Rosa" and "Santa Paula," which entered service twenty-six years ago. Finally, the builder—Newport News Shipbuilding and Dry Dock Company—has distinguished itself as a builder of fine ships. Its prodigious output of military and commercial vessels includes the S.S. "United States," and the 1046ft long supercarriers U.S.S. "Forrestal" and U.S.S. "Ranger," and its current contracts include the first nuclear-powered aircraft carrier.

The "Santa Rosa" was launched on August 28, 1957, and left on her maiden voyage on June 26, 1958. The "Santa Paula" was launched on January 9, 1958, and left on her maiden voyage on October 17, 1958. The new vessels were designed primarily for the Grace Line's year-round, twelve-day cruises to Caribbean ports, sailing every Friday from New York. But their fuel-oil capacity gives these vessels a cruising range in excess of 10,000 miles. This is slightly less than three times the scheduled route between New York, the Caribbean and South America. The vessels reflect the owner's and designers' emphasis on passenger comfort and convenience, and the liners boast an array of modern features with that end in mind. These range from the anti-roll, fin stabilisers, completely air-conditioned rooms and public spaces to the arrangement of the "lounge-or-play" areas. The new Grace liners, in addition, offer an important premium to their passengers. It is claimed that no other ships afloat equal their space-per-passenger ratio. The following table shows the main particulars of the "Santa Rosa":—

Length, overall	583ft 7in
Length, between perpendiculars	534ft 9in
Beam, moulded	84ft
Draught to design waterline, moulded	26ft
Depth to "A" deck, moulded	51ft 3in
Camber "B" deck and above	6in
Displacement tonnage (estimated)	19,364
Gross tonnage (estimated)	15,000
Net tonnage (estimated)	7,800
Propulsion	Twin-screw turbines
Horsepower, normal	20,000 s.h.p.
Speed, normal	20 knots
Passengers (all first-class)	300
Crew	246
Dry cargo bale cubic	337,000 cubic feet
Refrigerated cargo	81,000 cubic feet

Design of Vessel

In the "Santa Rosa" all the staterooms for the 300 passengers are outboard and each room is equipped with private bath. The vessel is fitted with eight decks and eleven main transverse watertight bulkheads divide the ship into twelve thwartship compartments. The vessel meets a two-compartment standard of subdivision and damaged stability. The shipyard utilised the sub-assembly method of construction where feasible, and these prefabricated units ranged from a few tons up to the 73-ton stern-frame assembly. The latter, of cast steel, was pre-assembled together with sections of the adjacent structure, including "D" deck and below. It then was stress relieved as a unit. The shell of the ship was constructed with riveted seams and welded butts with the exception of the bow and stern, where welding was used exclusively.

The scantlings and welding of the boundary structure of the No. 1 and No. 6 holds between the inner bottom and deck above permit ready conversion of these holds for carriage of cargo oil. As such the welding in these spaces meets the same standards required for deep tanks. The design avoided the placing of stairways, lift trunks, vents, &c., and other such openings in the strength decks outboard of the 12ft girder line on either side of the ship. Small openings for pipes, where permitted, were suitably reinforced and well rounded. Built to the American Bureau of Shipping's highest class for this type of ship, the vessel also meets or exceeds all U.S. Coast Guard requirements, the standards set forth at the International Convention for the Safety of Life at Sea (London, 1948), and the International Load Line Convention (London, 1930). Similarly, the safety at sea standards designated in Senate Report No. 184 of the seventy-fifth congress are met.

The vessel presents an attractive profile with full-bodied, but sleek, hull lines. It has a rounded forward house and stepped superstructure aft. A broad streamlined elliptical outer funnel adorned with the Grace Line's black, white and green markings, caps the white superstructure amidships. A modern, broad-based radar mast, raked aft, tapers to narrow proportions as it rises from the top of the house. The superstructure forward is set back sufficiently to enhance the vessel's fore section, which tapers to a well-raked bow. This expanse of deck accommodates the hatch openings for No. 1 and No. 2 holds, a pair of kingposts and attendant derricks and cargo-handling gear.

Aft, the superstructure steps down to a generous expanse of deck at the promenade and main deck levels. Two pairs of kingposts are provided aft. One set serves the cargo gear for the promenade deck No. 5 hold, which is fitted with flush, watertight hatch covers. The after kingposts serve the No. 6 hatch which opens on "A" deck. The vessel has additional cargo holds, No. 3 and No. 4, which are served by sideports exclusively. In addition to hatch loading by winch gear, the Nos. 2, 5 and 6 holds also are provided with sideports. In all, twenty sideports are fitted—ten on each side. Of these, fourteen are for cargo loading, two are for ship's stores and crew boarding, two are for passenger boarding and two for oil loading.

Interior Design

The interiors of the new "Santa Rosa" and "Santa Paula" were executed by two firms. Eggers and Higgins served as interior architects and Smyth, Urquhart and Marckwald acted as interior decorators. In planning the interiors special consideration was given to the fact that these ships will operate year round on a regular warm-weather route and visit tropical countries. The theme of the decor has been termed "comfortable modern," with the accent on gaiety. It is carried out with gay colours, cool-looking fabrics and contemporary decorative arts. The design motifs relate primarily to Caribbean and South American culture. Ocean blues and greens, yellows, reds, and oranges and a score of white tones were utilised in the interior colour schemes. All the fabrics which went into the new liners were specially designed and were selected not only for pattern, colour and texture, but also for durability and fire-retarding qualities.

The furniture, while in contemporary designs, was selected with comfort in mind. Framed of fine mahogany and oak, the chairs and sofas are upholstered in a variety of patterns, textures and colours. The tables are equally decorative with ornamental tops of glass, marble, ceramics, &c.

Arrangement of Decks

The uppermost deck is referred to jointly as the Navigating Bridge and La Playa Sports Deck. As the name connotes, this deck serves dual and widely differing functions. Forward is the bridge house with the navigating bridge and chart room, &c.; the bridge is fitted with navigating equipment and essential ship-safety system controls and communication equipment of latest design, including radar, loran, gyro compass, automatic course recorder and steering controls by Sperry.

The remaining three-fourths of the deck is allocated to passenger recreation. The point of demarcation between the navigating and recreation areas is the expanse of open-air deck directly abaft the bridge house and devoted to the usual shipboard games. Immediately aft is the enclosed and aluminium-covered La Playa house which is bounded by full-height vertical windows on three sides. To port and starboard are broad promenade areas which run the full

length of the house. The after end of the enclosed space gives way to the swimming pool and " beach area."

The swimming pool, which measures 34ft 6in by 22ft 6in, is constructed of " Lukens " monel-clad steel and has a recessed anti-splash overflow rim which prevents water from overflowing and wetting the beach area. Bordering the pool is a raised " beach " area which is decked with dark-green " Neotex." This is a trowelled-on, rubber-based material, impervious to water, which provides a sure-footed surface. The pool is arranged with its longer dimension running athwartship and there is ample space on either side for deck-chair sunbathing. A large area abaft the pool extends to an after bulwark, along which a series of six scalloped recesses provides table groupings, each having a built-in bench and beach umbrella.

The broad funnel casing has its forward interior section stepped in three levels. Fan machinery is housed in the two uppermost flats and an emergency generator room and a battery room are provided at the base. The funnel design reflects extensive wind-tunnel tests to determine the optimum shape to reduce back eddies of exhaust gases at all wind angles. To protect the passengers from annoying soot particles, " Uniflow " soot extractors, manufactured by the Marine Products and Engineering Company, were fitted in the three boiler uptakes. Each extractor incorporates a stationary cone and vane assembly of vortex design which removes entrained carbon and sparks from the combustion gases by centrifugal force.

Directly below the La Playa deck is the sun deck, which is mainly assigned to de-luxe passenger suites and staterooms and to accommodation for the ship's officers. Encircling the entire house is an open promenade.

The promenade deck is devoted almost entirely to public rooms. Occupying the full deck width forward is the " Caribbean Lounge." This room is semi-partitioned by mirrored bulkheads to form five open-faced alcoves that permit an informal arrangement of furniture. A series of picture-length windows provides an unrestricted view of the sea. The lounge was conceived to play a multiple part. It is furnished with writing desks, card tables, a piano and a book alcove, in addition to comfortable sofas and easy chairs. A large, translucent-glass mural worked in colours of blue and green depicts "Currents of the Caribbean." Two of the central panels open to reveal a concealed altar. Aft of the lounge is an athwartship foyer, and just forward of amidships is the dining room situated between covered promenades to port and starboard. The aft end of the dining room is divided by the machinery casing to form a figure " U." Eighty-four tables in a variety of shapes seat from two to eight persons and serve the entire passenger complement at a single sitting. The machinery casings are camouflaged by an aluminium-leafed glass panel which can be lowered to facilitate projection of films from the projection room behind it.

The next section of this deck houses the galley and food preparation areas. These range across the full width of the house. The galley proper is on the centre line, surrounded by the various food preparation and service departments.

Aft of the galley area is a broad thwartship entrance foyer opening to the " Club Tropicana," which is a festive gathering place for the more formal activities in the evening. In the centre is an oval-shaped dance floor, positioned diagonally, and adjacent is the raised orchestra dais. To port, forward, is a free-form bar, while continuous banquettes or settees faced by small cocktail tables and chair groupings, extend along the outboard bulkheads. The inner area of the club also has small table groupings fanning out from the dance floor. Here again the designers used windows generously to provide light and panoramic views of the sea. A sizeable open deck area behind the " Club Tropicana " completes the arrangement of this deck. Here, a flush, single-hinge hatch cover gives access to No. 5 hold and enables the area to be used for deck games. " A " deck is the longest superstructure deck on the ship. The weather deck extends 152ft forward to the bow. In this forward section are located the windlass, booby hatch access to " B " deck and the No. 1 and No. 2 hatches fitted with hinged, watertight covers. The enclosed section of " A " deck extends aft 321ft, and passenger accommodation is arranged port and starboard outboard along the entire length of the house with the exception of a lounge to port aft for female crew personnel. Six luxury suites are provided, three on each side, and the remaining accommodation is mainly two-berth staterooms with twin beds. The balance of the passenger stateroom accommodation is on " B " deck with crew accommodation, machinery spaces and cargo spaces being situated on the remaining " C," " D " and " E " decks.

Fig. 1—Club Tropicana room, for formal shipboard activities, with dance floor and bar

Cargo Handling

The cargo handling gear of the " Santa Rosa " incorporates two separate systems. Holds 1, 2, 5 and 6, which are fitted with deck hatches, are equipped with a " Mariner " burtoning system. In addition, holds 2, 5 and 6 are each served by two sideports, one port and one starboard. Holds 3 and 4, which have no weather deck hatches, are each served by four sideports and an unusual cargo conveyor-lift system.

The operating gear for the fourteen cargo sideports at " C " deck and the additional units for passenger and crew stores loading were manufactured by Walz and Krenzer, Incorporated. The cargo units are of one piece, horizontal-sliding pattern. They first move slightly inboard and then slide forward or aft to provide a 7ft 10in by 9ft clear opening. Each sideport has its own independent electro-hydraulic system and it requires only three minutes for one man to open a sideport from the completely secured position. The controls and hydraulic cylinders for actuating the doors are mounted adjacent to the opening. Being of compact design, these controls do not obstruct the area and are protected from possible damage. A patented arrangement synchronises the four door-positioning cylinders so that all four corners of the door slide inboard uniformly. The working pressure of the hydraulic system is 1200 lb per square inch. All components are of shock-proof construction and fire-retardant liquid is the working fluid. A hand-pump is supplied to permit sideport operation in the event of power failure.

Hatches 1, 2, 5 and 6 each are fitted with 10-ton derricks, while additional 5-ton derrick gear is provided for holds 2 and 6. These units are served by twelve " Lake Shore " cargo winches, each powered by a 50 h.p. General Electric d.c. drive.

Automation has been applied to holds 3 and 4 to an unusual extent in the marine field. An automatic cargo-handling system comprising horizontal triple-chain conveyors and a vertical cargo lift serves all levels of each of these holds. The system was designed by the Gifford-Wood Company to operate as follows : After the sideport door is opened, a 16ft portable conveyor weighing 8000 lb is projected out of the port 12ft in cantilever fasnion. This represented a difficult design problem which was solved by the use of hydraulics. The conveyor-handling system utilises the sideport hydraulic-power system. Four hydraulic cylinders actuating a pair of slotted steel arms actuate the portable conveyor.

When in position outboard, the portable conveyor aligns with the fixed conveyor on deck. The fixed conveyor leads to a vertical cargo lift which serves the three lower decks. The portable conveyors can be moved to serve either port or starboard sideports. Fork-lift trucks deposit pallet loads of cargo weighing up to 6000 lb on the portable conveyor. From here the cargo moves inboard on to the fixed conveyor which transports it to a short conveyor which delivers it to the lift. From a main control station adjacent to the lift, an operator can direct the lift to deposit the load to any of the three decks below. There, it is automatically discharged on to a 6ft conveyor. A fork-lift truck picks up the load and stacks it as desired.

The system is synchronised by limit switches which regulate the flow of pallets. Thus, the departure of one pallet will actuate the conveyor behind to deposit a new one in its place. If the operator locks the control button down, pallets will be taken below as fast as they can be placed on the outboard conveyor and cleared from the lift discharge conveyor in the hold. In discharging cargo the sequence of operations is reversed.

Stabilising Gear

A pair of Sperry " Gyrofin " stabilisers are fitted to counter the roll-generating forces, and have the ability to dampen rolls by as much as 90 per cent. This system incorporates two adjustable hydrofoil fins installed port and starboard above the turn of the bilge just abaft amidships.

A gyroscope-accelerometer unit senses the beginning of a roll and provides a signal proportional to the roll velocity. A linear accelerometer and an angular accelerometer also produce signals. A magnetic amplifier computer combines and modifies the signals, computes the lift and sends command signals to the hydraulic servos which control the fin angle. The signal continues to actuate the fins until it is cancelled by a feedback signal produced by the lift of the fins as indicated by the deflection of their shafts. Since each fin must produce feedback to cancel its own signal, the righting moment is produced as a couple. To provide against possible derangement of the lift feedback, fin-angle feedback also is provided.

A force of up to 70 tons can be produced by each of the two fins to oppose the ship's tendency to roll. The completely automatic control of the fin mechanisms is effected from a console in the pilot house. The console is provided with three selectors for fine adjustment by the watch officer. In this way list correction, sea conditions and vessel speed are compensated. The fins are projected or housed by the engine watch on orders from the bridge.

Propulsion Machinery

The operating level of the twin-screw propulsion plant is balanced, port and starboard. Every component on the port side is matched by its counterpart on the starboard side. The arrangement fore and aft is as follows : forward to port and starboard are situated two of the three General Electric 1250kW, 450V, 60 c/s,

three-phase turbo-alternators. Any two of the three alternators are sufficient to handle the ship's electrical load. Working inboard from port along the forward bulkhead there are a pair of General Electric group control panels: one panel houses the controls for vital electrical auxiliaries, the other serves non-vital equipment. This arrangement is duplicated to starboard. On either side of the centre line forward are twin throttle and gauge-board stations. Each set of manœuvring valves serves its own propulsion turbines. Directly abaft the throttle platform and sited on the centre line is the third 1250kW turbo-alternator. The log desk and telephone enclosure is immediately forward of this unit.

Port and starboard of the centre line alternator are the twin sets of propulsion turbines and reduction gears. The twin plants produce a total normal cruising output of 20,000 s.h.p. The maximum continuous rating for merchant service is 22,000 s.h.p. at 124 propeller revolutions per minute. The maximum U.S. Navy rating is considerably in excess of 22,000 s.h.p. Each of the two sets of turbines consists of one high-pressure and one low-pressure turbine driving a four-bladed manganese-bronze propeller through double-helical, double-reduction articulated gears. The turbines and gears are of General Electric make. The h.p. turbines are equipped with nine impulse stages, and eight impulse stages are provided in the l.p. turbines. The l.p. casings also house the astern turbines at the forward end. The propulsion units were designed to permit the power output to be developed equally between the h.p. and l.p. units. The 22,000 s.h.p. rating is developed with the h.p. turbines turning at 6670 r.p.m. and l.p. turbines at 4200 r.p.m. This is stepped down to 124 r.p.m. at the propeller shafts. Extraction steam is bled from the seventh stage of the h.p. turbines to supply the Worthington de-ærating feedwater heater. The steam air heaters are served by cross-over bleeders. Extraction steam also is taken from the fourth stages of the l.p. turbines to supply the evaporators and low-pressure feedwater heater.

The remainder of the upper level is arranged as follows: to port and starboard aft are two Griscom-Russell submerged-tube, double-effect evaporators, each having sufficient capacity to supply 100 gallons per day per person in excess of make-up needs. Inboard at the after bulkhead is a 3500-gallon lub-oil storage tank to starboard and two 1800-gallon lub-oil gravity tanks to port location, and on the centre line is the main electrical distribution switchboard.

The balanced arrangement of upper-level machinery is reflected in the lower-level layout. The two main condensers with scoop injection systems, condensate and vertical propeller circulating pumps, have their auxiliaries and valves in like locations, port and starboard. So do the auxiliary condensers situated in the forward wing spaces. The third turbo-alternator condenser is arranged longitudinally along the centre line. Each of these condensers is fitted with two centrifugal condensate and circulating pumps. Further outboard, port and starboard, are the two sets of main engine reduction gears.

The three Babcock and Wilcox, two-drum water-tube boilers are arranged athwartship. Steam conditions are 600 lb per square inch gauge and 850 deg. Fah., and each unit supplies 77,900 lb of steam per hour at its continuous maximum output. The operation of two boilers is sufficient to steam at 20 knots. Each unit is double cased and fitted with superheaters and economisers in addition to steam air heaters. The furnaces have a tangent water-cooled side roof and rear walls. Babcock and Wilcox refractory front walls complete the enclosure. Each boiler is fired with three "Iowa" oil burners with mechanical atomisers installed in the front wall, and supplied with fuel at 300 lb per square inch gauge. Each boiler has a submerged-coil desuperheater capable of desuperheating 25,000 lb per hour.

The Bailey combustion-control board is on the lower level of the boiler room to port of the centre line. Here a fuel-oil air ratio controller is automatically adjusted for all boilers to maintain efficient and economical combustion. The combustion-control board is fitted with selector valves for hand or automatic operation. Mounted here are the various steam, feed and temperature gauges. Bailey also supplied the feedwater control system, incorporating air-operated, two-element feedwater regulating valves. The primary control of the regulators is from steam-flow measurements. In this way feed into the boiler is precisely equal to the steam flow out of the boiler.

Fig. 2—Loading of cargo on to outboard receiving conveyor by fork-lift truck

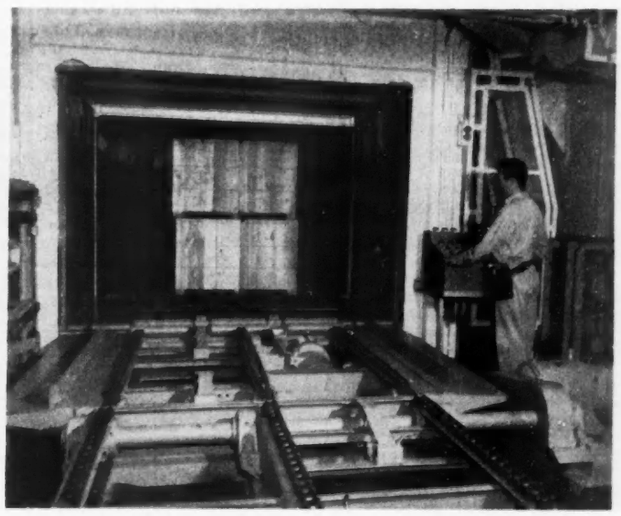


Fig. 3—Triple-chain conveyor and cargo lift with pallet-mounted cargo and operator at central control panel

55th A.C.I. Convention in Los Angeles

THE American Concrete Institute will hold its annual convention in Los Angeles, February 23–26, 1959. An added attraction is the student competition for concrete designs and applications sponsored by the A.C.I. Southern California Chapter. The competition is open to all students in southern California colleges regularly enrolled in engineering or architecture. Four cash awards will be given for the best presentations of projects using Portland cement concrete in the form of scale models, architectural renderings, perspective drawings or pictorial presentations. Entries will be on display at the convention and prizes will be presented at the annual awards luncheon.

The first general session Tuesday afternoon will include possible revisions of A.C.I. by-laws and proposed A.C.I. standards. The standards to be presented for adoption cover hot weather concreting, proportioning of lightweight aggregate structural concrete, and measuring, mixing and placing concrete. Concurrent sessions Wednesday morning will feature construction, and special problems in concrete. The construction session will include papers on erection of precast concrete; joinery of precast elements; concrete pavements on cement-treaded subgrades; qualification plan for ready-mixed concrete plants, and cast-in-place concrete pipe. Special problems in concrete will include discussions of properties of shielding concrete; design and performance of concrete special purpose blast resistant structures; influence of grade of steel on blast resistance of reinforced concrete beams, and surface cooling of mass concrete as a means of controlling cracking.

Concurrent sessions Wednesday afternoon will be on design and analysis, and concreting materials and methods. Papers concerning design and analysis will discuss design of prestressed concrete lift slabs for deflection control; effect of longitudinal forces on a portal frame supporting a highway bridge deck; prestressed concrete shells for grandstands and roof (featuring the Hippodrome at Caracas, Venezuela), and laboratory research, stresses, and deflections in pavements continuously reinforced with deformed bars. Concreting materials and methods will feature papers on the evaluation of concrete and mortar mixes; properties and application of shotcrete to new buildings; controlling tremie concrete with admixtures; and concrete and concrete materials for Glen Canyon dam.

Sessions Thursday morning will feature design research and products and precast elements. Design research will report on the effect of bar cut-off on bond and shear strength of reinforced concrete beams; shear strength of two-span continuous reinforced concrete beams; torsional resistance of reinforced concrete, and the behaviour of a continuous concrete slab prestressed in two directions. The session on products and precast elements will discuss precast and prestressed folded plate slabs; plastic forms for architectural concrete; exposed aggregate type of decorative panels; glazed face concrete block, and linings for concrete pipe and structures under sewage conditions.

The technical programme will culminate Thursday afternoon with the annual research session, an open meeting of A.C.I. Committee 115. A group of short papers will be presented on research techniques and preliminary results of investigations now in progress of the future developments in concrete and concrete construction.

Personal and Business

Appointments

MR. W. F. G. WITHERS has been appointed general sales manager of Aero Controls, Ltd.

MR. M. HAMSHAW has been appointed managing director of Chemical Engineering Wiltons, Ltd.

MR. M. SOFFA, general manager of Jeltek, Ltd., has been appointed a director of the company.

MR. J. E. T. HAILE has been appointed assistant managing director of Rank Precision Industries, Ltd.

MR. R. EDWIN MCALPINE has been appointed chairman of The Nuclear Power Plant Company, Ltd.

THE HON. J. KENNETH WEIR has been elected a director of The International Nickel Company of Canada, Ltd.

AIR MARSHAL SIR RAYMOND HART, K.B.E., M.I.E.E., has been appointed director of the Radio Industry Council.

MR. C. R. JONES and MR. P. K. RICHARDS have been appointed directors of John Thompson Water Tube Boilers, Ltd.

MR. STEVEN P. J. WOOD, president of the Warner Electric Brake and Clutch Company, has joined the board of Westool, Ltd.

MR. JOSHUA SIEGER has been appointed applications engineering consultant to the electronic division of International Engineering Concessionaires, Ltd.

MR. W. L. VALENTA has been appointed sales development engineer of Workington Iron and Steel Company, a branch of The United Steel Companies, Ltd.

MR. J. EDWARDS, A.M.I.Mech.E., A.C.G.I., has been appointed to the chair of nuclear science and technology, which has been established at the Royal Naval College, Greenwich.

JOHN I. THORNYCROFT AND CO., Ltd., states that Mr. I. Cameron will take over the duties of general manager of the company's Southampton works upon the retirement of Captain G. Villar, R.N. (retired).

BRITISH RAILWAYS announce the following appointments in the Scottish Region :—Mr. H. Cheetham, supplies and contracts manager ; Mr. A. E. Bainbrigge, supplies officer ; Mr. A. R. D. Roberts, contracts officer.

DR. D. V. ATTERTON has been appointed managing director of Foundry Services, Ltd., in succession to Mr. E. Weiss, who has relinquished the post in order to devote more time to the affairs of the parent company, Foundry Services International, Ltd.

THE BRITISH TRANSPORT COMMISSION has announced the appointment of Mr. M. R. Bonavia as director of studies at the British Transport Staff College, Woking. He was formerly principal officer (modernisation) in the general manager's office, Eastern Region of British Railways.

W. H. DORMAN AND CO., Ltd., has announced the following appointments :—Mr. H. B. McAuslan, Far Eastern representative ; Mr. B. Ginesi, European and Scandinavian representative ; Mr. W. G. Reid, Midlands area representative ; Mr. A. J. Wilkin, London area sales representative.

MR. H. W. KIRKBY has been appointed a director of Thos. Firth and John Brown, Ltd. Dr. F. W. Jones has become a local director of the company and manager of the Brown Firth Research Laboratories. He succeeds Mr. J. Woolman, who has retired after thirty-nine years in the company's service.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces the appointment of Mr. C. S. F. Lane as regional manager for Australia and New Zealand in the overseas organisation in London. He succeeds Mr. R. H. Semple, who has been appointed to a senior executive post with an associated company in Australia.

Business Announcements

NELDCO PROCESSES, Ltd., has moved to Crossway House, Bracknell, Berks.

MR. R. W. P. HOLT, M.I.Mech.E., a director of Widnes Foundry and Engineering Company, Ltd., has retired.

MR. E. CHATTERTON has relinquished his position as chief engineer of the piston engine division of D. Napier and Son, Ltd.

MR. GEORGE A. WILLIAMSON, M.I.Mech.E., director of engineering of Firestone Tyre and Rubber Company, Ltd., retired on January 30.

R. H. WINDSOR, Ltd., states that the London office and showrooms of the Windsor group of companies are now at 76, Jermyn Street, S.W.1 (telephone, Whitehall 0411).

COOPER AND CO. (BIRMINGHAM), Ltd., announces that its Midland Sales Office and Branch Works is now situated at Felt Works, Seeley's Road, Greet, Birmingham, 11 (telephone Victoria 5417-9).

STEEL AND CO., Ltd., Sunderland, states that it has purchased the crane business of F. Taylor and Sons (Manchester), Ltd. It has also made an offer to buy the whole of the ordinary stock of R. H. Neal and Co., Ltd.

MR. A. J. STEPHEN BROWN, a director of Stone-Platt Industries, Ltd., and joint managing director of J. Stone and Co. (Holdings), Ltd., has left this country by air to visit the Stone Group's companies and associates in India, Australia and U.S.A.

G. AND J. WEIR HOLDINGS, Ltd., and CATTON AND CO., Ltd., announce that the merger of Catton and Co., Ltd., and Weir Foundries, Ltd. (a subsidiary of G. and J. Weir Holdings, Ltd.), has now been concluded. A new holding company, Weir-Catton, Ltd., has been formed.

SIR JOHN GALLWEY AND PARTNERS state that whilst the offices of their associated company Protim, Ltd., are being moved to the City, they and their Gallwey Protim Eradication Service will continue to operate from their old address, Evelyn Street, London, S.E.8 (telephone Tideway 4611).

F. PERKINS, Ltd., has formed a private company, Perkins Outboard Marine, Ltd., to market the company's new petrol outboard motors. The directors are Mr. M. I. Prichard, Mr. T. H. R. Perkins, Mr. J. G. Dawson and Mr. D. F. W. McNair. The secretary is Mr. T. A. Read.

HADFIELDS, Ltd., announces that its home sales representatives are to act on behalf of the Hadfields Group of Companies as a whole including Millspaugh, Ltd., and its subsidiaries. This arrangement does not include Millspaugh pulp and paper making machinery or the plant for paper making works erected by Millspaugh-Wimpey.

MR. J. A. FRASER has relinquished his directorships in companies in the Southern Areas Electric Corporation group, and has formed a new company, J. Alistair Fraser, Ltd., 79, Mount Street, London, W.1 (telephone, Grosvenor 3153), to act as sales and marketing consultants in the domestic electric appliances industries and allied trades.

HERBERT MORRIS, Ltd., Loughborough and STEELS ENGINEERING PRODUCTS, Ltd., Sunderland, have entered into a reciprocal agreement, whereby Morris mobile, truck-mounted, and rail cranes will in future be manufactured at the Sunderland factory, and Coles overhead travelling cranes and electric hoists will in future be manufactured in the Loughborough factory.

H. AND L. MATHEW, Ltd., announces that the companies within the " Matbro " organisation will now be known as the Matbro Group of Companies. Companies included in the group are : Mathew Brothers, Matbro Works, Sandy Lane North, Wallington, Surrey ; Mathew Brothers, Matbro House, Beddington Lane, Croydon Surrey ; Power Plant Hire (Beddington), Ltd., Matbro House, Beddington Lane, Croydon, Surrey ; and Matbro, Ltd., Horley, Surrey.

HIGH DUTY ALLOYS, Ltd., announces that it has opened a new Midland area sales office at Queen's College Chambers, 38A, Paradise Street, Birmingham, 1 (telephone Midland 3286), to handle sales of Hiduminium sheet, extrusions, tube and castings. All home market inquiries and quotations in regard to forgings will in future be handled from a new sales department at the forging division, Windsor Road, Redditch, (telephone, Redditch 711). Mr. G. F. Ingram has been appointed sales manager.

Contracts

W. H. ALLEN, SONS AND CO., Ltd., announces the receipt of an order for two back pressure turbo-alternators for installation on board a 32,350 tons deadweight oil tanker being built by the Broken Hill Pty. Company, Ltd., Whyalla, Australia, for the Ampol Petroleum Company, Ltd. Each turbine will take steam at 585 lb per square inch gauge and 840 deg. Fah. and drive, through reducing gears, a 600kW, three-phase, 50 c/s, 415V alternator at 1500 r.p.m.

RICHARD COSTAIN, Ltd., has been awarded a contract valued at £4,500,000 for the construction of a deep-water berth for large tankers in the Persian Gulf, as a joint venture with the Raymond International and DeLong Corporation. The berth will be constructed about 20 miles out to sea off the mouth of the Shatt-al-Arab River, and will consist of a centre island 400ft by 240ft, with mooring dolphins at either end connected by steel bridges, and thence by other bridges to a tug berth and helicopter deck at one end and an accommodation platform at the other. The overall length of the structures will be about ¼ mile. The island will be a structural steel frame on steel tubular piles, with a timber deck, piles and steelwork being supplied by South Durham Steel and Iron Company, Ltd. A shore base will be established at the port of Fao, in Iraq, for the assembly of materials which will be used in the construction. Work is to start immediately on the fabrication of the steel and the construction of specially designed barges, which will be towed out to the Gulf. It is hoped to complete the contract by January, 1961. The project is being undertaken for the Basrah Petroleum Company, Ltd. The consulting engineers are Messrs. Rendel, Palmer and Tritton.

THE ENGLISH ELECTRIC COMPANY, Ltd., has received an order valued at approximately £1,500,000 from the Sudan Railways for fifteen 1875 b.h.p. main line diesel-electric locomotives for the 3ft 6in gauge. The locomotives will have full-width bodies, with a driving cab at each end and will be carried on two three-axle motor bogies. Weight in working order will be 99 tons and maximum speed 53 m.p.h. Dynamic braking will be incorporated. Power will be supplied by English Electric twelve-cylinder CSVT diesel engines manufactured at Preston, where the traction motors and other electrical equipment will be produced. The Vulcan Foundry, Ltd., Newton-le-Willows, a member of the English Electric Group, will be responsible for construction of mechanical parts and for erection of the locomotives.

TAYLOR WOODROW (OVERSEAS), Ltd., in collaboration with the Compagnie Industrielle de Travaux, of Paris, and the Utah Construction Company, of San Francisco, has been awarded a contract to build a single-track railway in French Equatorial Africa for the Compagnie Miniere de L'Ogooue, which is developing extensive manganese deposits in the area of Franceville. The value of the contract is nearly £9,500,000. It is expected work will start very shortly. The line will be 198 miles long and of metre gauge. It will run from Mayoko in French Equatorial Africa to a point near Brazzaville, where it will connect with the Congo-Ocean Railway to provide a direct run for the manganese ore to the seaport of Pointe Noire. It will run through mainly " jungle " country and other difficult terrain, and will be finished in three years. The work will involve the removal of about 12,250,000 cubic yards of earth, the construction of two major bridges, a number of viaducts and culverts and the setting up of quarries.

Miscellanea

INSTITUTE OF MARINE ENGINEERS.—At a short ceremony which took place on February 2, in the Lecture Hall of the Memorial Building, Mr. Watkinson, the Minister of Transport and Civil Aviation, handed over into the custodianship of the Institute of Marine Engineers, three volumes forming the Roll of Honour of the Merchant Navy and Fishing Fleets for the 1939/45 war. These were accepted by the President, Mr. E. L. Denny, for safe keeping by the Institute.

EPOXIDE RESIN DR19120.—A hot curing system (consisting of epoxide resin DR19120 used in conjunction with hardener DQ19121) has been specially developed by Bakelite, Ltd., 12–18, Grosvenor Gardens, London, S.W.1, for potting and casting in the electrical industry. The hardener is melted at 130 deg. Cent. and added to the resin which has been heated previously to 120 deg. Cent. As only slight exothermic action occurs during curing large masses can be cast without bubbling or cracking. Typical characteristics of the system are : resin/hardener ratio, 100/30 ; initial viscosity at 120 deg. Cent., 160 c/s ; working life at 120 deg. Cent., 1½ hours ; setting time at 120 deg. Cent., 3½ houts.

GAS TURBINE FOR INDUSTRIAL DUTY IN CANADA.—The first British gas turbine for industrial duty in Canada is now being delivered. Manufactured by Ruston and Hornsby, Ltd., Lincoln, the gas turbine has been ordered by Canadian Industries, Ltd., an associate of Imperial Chemical Industries, and will be used in the production of polythene at Canadian Industries' plant in Alberta. The gas turbine will replace a steam turbine driving a refrigeration compressor employed in the polythene process. The plant uses natural gas obtained from local sources as the main raw product in the production of polythene, and the gas turbine will burn this natural gas after the ethane has been extracted (to produce ethylene, which in turn is converted to polythene). In effect, this means that the gas turbine will utilise a partially-waste product as fuel and thereby show considerable savings in the plant's running costs. This gas turbine, known as the TA, is normally rated at 1260 b.h.p.

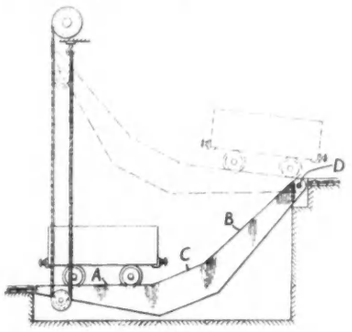
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings, unless otherwise stated. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 51, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

RAILWAY ENGINEERING

807,474. June 22, 1956.—Wagon Elevators, Simon-Carves, Ltd., Bird Hall Lane, Cheadle Heath, Stockport, Cheshire. (*Inventor: Wilfrid Harry Worsley.*)

This invention relates to means by which containers such as railway wagons can be elevated and or lowered. One embodiment of the invention is shown in side elevation in the drawing. The means for lowering or elevating the railway wagon comprises a



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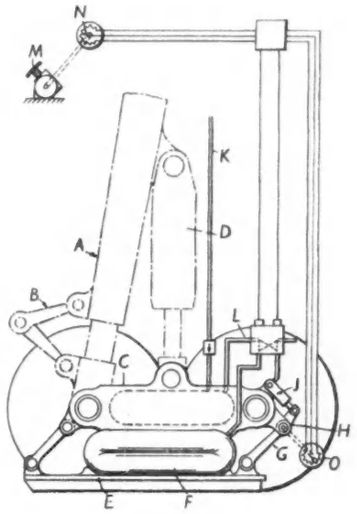
beam having straight portions *A* and *B* and an inclined connecting portion *C* which are provided with a railway track. The beam is pivoted at *D* and a winch moves the beam around this pivot. The wagon is run on the track on to the straight part *A* of the beam. The winch then lifts the beam until the flat part *B* takes up a substantially horizontal position in line with the upper railway track. During this lifting operation the wagon gravitates on to the part *B* and when the beam is in its upper position the wagon can be handled, loaded, or unloaded, on the beam, or run off the beam on to the upper track. If it is desired to lower the railway wagon, the operation is reversed. The portion *C* of the beam serves to brake the movement of the railway wagons gently when they are moving on to the beam. According to another embodiment of the invention, the beam is arranged transversely to a number of tracks. A bogie adapted to travel along the beam, carrying a track section extending across the beam, can be brought into alignment with the various tracks as the beam is raised or lowered.—*January* 14, 1959.

AIRCRAFT ENGINEERING

807,554.—September 23, 1955.—Aircraft Brake Mechanism, Dowty Equipment, Ltd., Arle Court, Cheltenham. (*Inventor: Richard Northam Knights.*)

This invention relates particularly to a form of aircraft brake mechanism wherein a member adapted for frictional engagement with the landing surface is mounted on a wheeled undercarriage for movement towards and away from the ground. The undercarriage comprises a retractable leg *A* having an upper and a lower component telescopically slidable together and having the torque linkage shown generally at *B* interconnecting the components in known manner to prevent relative rotation. The lower end of the leg supports a pair of leading wheels and a bogie or lever *C* is pivotally mounted on the wheel axle at its forward end. The trailing end of the lever supports a second axle on which are mounted a pair of trailing wheels. A liquid spring shock absorber *D* is fitted on the leg and this undercarriage structure is generally constructed as described in Specification No. 670,889. The ground-engaging friction brake for use against a hard runway surface fitted to the undercarriage is generally of the kind described in Specification No. 728,176. The construction of brake mechanism in accordance with the present invention has a brake shoe *E* on which is mounted a friction element. A pneumatic pressure actuated device in the form of an extensible bag *F* is interposed between the lever *C* and the shoe. The rear link *G* of the shoe assembly has an extension lever arm *H* and a brake shoe retraction jack *J* is pin-jointed between this arm and a lug on the lever *C*. The lever *C* is hollow and its interior acts as a pneumatic accumulator, to which high pressure air is admitted through a pipe *K*. An outlet pipe *L* from the accumulator leads to a control valve which has a connecting pipe to the extensible bag and a pipe to the brake shoe retraction jack. This valve incorporates two valve-operating solenoids and is so arranged that as pneumatic pressure is admitted to the bag to increase the ground bearing pressure, the retraction jack *J* is vented and vice versa. The valve is controlled to regulate the braking pressure under the remote control of the pilot of the aircraft by a pedal *M* which



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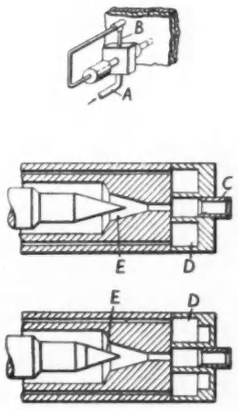
operates through a rack and pinion and a shaft to turn the contact arm *N* of an input potentiometer in accordance with linear movement of the pedal. Through a feed-back potentiometer *O* the movement of the contact arm is co-ordinated with the pivotal movement of the shoe link. This electrical servo-mechanism thus regulates the movement of the friction element *E* towards and away from the ground in accordance with the displacement of the pedal.—*January* 14, 1959.

INTERNAL COMBUSTION ENGINES

807,540. June 4, 1957.—Fuel Injection Valves for Diesel Engines, Esso Research and Engineering Company, Elizabeth, New Jersey, United States of America.

This invention relates to improvements in the injection of heavy fuels into diesel engines and particularly to means by which large marine engines may be operated on fuel which is considerably heavier than that for which they were originally designed. According to the invention, by relatively minor and inexpensive redesign of certain critical parts in the fuel injection system, it has been found possible to



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switch over to full-time operation of large engines on the heaviest grades of residual oil. The injection of these fuels in such a manner as to avoid the serious deposit problems hitherto encountered is a primary object of the invention. Referring first to the upper drawing, there is shown a detailed portion of a diesel engine cylinder wall, to which an injection nozzle assembly is secured by conventional connections. This nozzle comprises a feed line *A*, preferably steam jacketed or otherwise heated, so that the heavy oil can be brought into the valve at a suitable elevated temperature, preferably at least 150 deg. Fah. and desirably approaching 250 deg. Fah. or a little more. A balancing line *B* is also provided through which fuel under pressure is applied to the valve plunger to aid in closing the valve to stop the injection of fuel. Referring to the conventional valve design shown in the middle drawing, when standard diesel fuel is fed, there are no substantial operating difficulties. However, when heavy residual type fuel is supplied, and the valve closure member is moved to closed position, it has been found to be quite impossible to obtain a clean cut-off of the fuel. As operation of the engine proceeds, there is gradually built up a deposit at portion *C* in the form of a hollow cone of carbon which ultimately clogs or seriously deflects or restricts the fuel flow. To improve the operation of the injection valve the jacketing of the injector nozzle tip was improved by cutting out additional metal in the cooling space *D*. By this means it was found possible to improve the operation somewhat by keeping the temperature of the fuel nozzle tip below a coking temperature of around 700 deg. Fah. or so. However, this improvement did not prevent the dribbling of fuel after a valve was closed. The eventual build-up of deposits continued. Referring now to the bottom drawing, it was found that the combination of a short annular surface on the valve needle, of identical taper angle with the valve seat, solved the problem, provided that the tip portion of the needle was machined to a conical angle greater by 2 deg. to 6 deg. than the angle of the valve seat. The optimum divergence of the needle surface between needle point and valve seat was found to be about 4 deg. However, a slight tolerance above and below this angle was found permissible, the critical range being between 2 deg. and 6 deg. Thus, as shown, the valve seat is provided with a conical taper having a convergent angle of not less than 20 deg. and not more than 40 deg., 30 deg. being generally preferable. The needle is made with a short seating surface of identical angle, the length of which may be one-eighth or one-half of the diameter of the needle before it tapers. The tip portion of the needle is machined to a convergent angle 2 deg. to 6 deg. greater than the valve seat angle, or 32 deg. to 36 deg. when the basic angle is 30 deg. Here, as noted above, the preferred angle for the needle tip was found to be about 34 deg. The portion *E* apparently is critical. The scientific theory of its operation is not clearly understood, but the improvement was found effective. The particular angle of the needle valve tip apparently has something to do with the optimum cut-off of the flow of fuel. Whatever may be the mechanism, it is stated, this simple change in the angle of convergence of the valve parts, plus the improved jacketing and cooling of the nozzle tip, have made it possible to operate large diesel engines full time on heavy residual oil of low quality, such as Bunker C quality.—*January* 14, 1959.

807,709. July 3, 1957.—Two-Stroke Internal Combustion Engines, Sulzer Frères, Société Anonyme, Winterthur, Switzerland.

This invention relates to multi-cylinder two-stroke engines in which the exhaust gas is controlled additionally by rotary valves through which the gas flows in series with the ports. According to the present invention at least one of the connections between adjacent rotary valves and the drive means is made by an axially and radially flexible coupling, of such a type that by releasing the couplings associated with any rotary valve it can be removed without dismantling other valves. Preferably the flexible coupling comprises an endless chain which encircles two sprockets. In a preferred embodiment the number of teeth on the sprockets is so selected that all the phase shifts of the rotary valves occurring in the series of cylinders correspond to an integral number of tooth pitches so that all parts of the rotary valves and their housings may be made interchangeable. One embodiment of the invention is specifically described by way of example with reference to a drawing. In this arrangement each sprocket of the chain coupling has twenty-four teeth, so that relative displacement of two sprockets by one tooth pitch corresponds to a 15 deg. phase shift, two tooth pitches to a 30 deg. phase shift and so on. It is thus possible with the twenty-four teeth to obtain all the rotary valve phase shifts normally encountered in a multi-cylinder engine without alteration to the rotary valve being necessary. All the valve housings and their parts are therefore mutually interchangeable. The same result could be obtained for less usual phase shifts by having a different number of teeth on the sprocket.—*January* 21, 1959.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Feb. 17.—ALDERSHOT AND DISTRICTS BRANCH: Queens Hotel, Farnborough, "Railway Electrification," D. B. Mackenzie, 7.30 p.m.

Wed., Feb. 18.—NOTTINGHAM BRANCH: Mechanics' Institution, Trinity Square, Nottingham, Annual Films Evening, 7.30 p.m. ★ WOLVERHAMPTON AND DISTRICT BRANCH: Chamber of Commerce, District Bank Chambers, Lichfield Street, Wolverhampton, "Recent Changes in Routing and Charging of Telephone Calls," H. L. Hitchin, 7.45 p.m.

Sat., Feb. 21.—OXFORD AND DISTRICT BRANCH: St. John's Hall, Marston Street, Oxford, "Electric Floor Warming," 7 p.m. ★ SOUTH EAST LONDON BRANCH: Visit to the National Physical Laboratory, Teddington, 2 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, Feb. 13.—MEDICAL ELECTRONICS GROUP: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Some Instrumentation Problems in Medical Electronics with particular reference to Electromyography," P. Styles, 6.30 p.m.

Thurs., Feb. 19.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "True Motion Radar," J. H. Beattie, 7 p.m.

Fri., Feb. 20.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Drummond Street, Edinburgh, "True Motion Radar," J. H. Beattie, 7 p.m. ★ MERSEYSIDE SECTION: University Club, Liverpool, "Electronic Welding Controls," C. R. Bates, 7 p.m.

CENTRAL LONDON PRODUCTIVITY ASSOCIATION

Thurs., Feb. 19.—21, Tothill Street, London, S.W.1., Discussion on "Introducing New Methods," 2.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., Feb. 18.—SCOTTISH REGION: North British Hotel, Edinburgh, "The Insulation of Industrial Buildings," J. Lawrie, 10.30 a.m. and "Case Histories of Fuel Savings," H. H. Grattidge, 2.30 p.m. ★ NORTH WESTERN REGION: Engineers' Club, Manchester, "The Use of Gas for Industrial Purposes," W. F. S. Howell, 2.30 p.m. ★ MIDLAND REGION: Chamber of Commerce, New Street, Birmingham, "Oil Burners for Small Steam Raising Plant," I. G. Bowen, 10 a.m. and "Supply Storage and Handling of Oil Fuels," A. Paterson, 2.45 p.m.

DIESEL ENGINEERS AND USERS ASSOCIATION

Thurs., Feb. 19.—Institute of Marine Engineers, Memorial Building, 76, Mark Lane, London, E.C.3, "The Application of Diesel Engines to Automatically Controlled Power Plant," K. L. Ives, 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Feb. 16.—BATH AND BRISTOL CENTRE: Showroom, South Western Electricity Board, Plymouth, "New Light Sources," F. Jackson, 7 p.m.

Tues., Feb. 17.—LIVERPOOL CENTRE: Merseyside and N. Wales Electricity Board Industrial Development Centre, Liverpool, "Son et Lumiere in Great Britain," H. Hewitt, 6 p.m.

Wed., Feb. 18.—NORTH LANCASHIRE GROUP: Demonstration Theatre, North Western Electricity Board, 19, Friargate, Preston, "As I See It," S. Mountain, 7 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Feb. 17.—EAST ANGLIAN SECTION: Lecture Hall, Public Library, Ipswich, "Production of a Cylinder-Head Casting in Grey Iron," L. W. Bolton, 7.30 p.m. ★ SLOUGH SECTION: Lecture Theatre, High Duty Alloys, Ltd., Slough, "Pattern-making Progress," B. Levy, 7.30 p.m.

INSTITUTE OF FUEL

Wed., Feb. 18.—YORKSHIRE SECTION: Royal Victoria Hotel, Sheffield, Discussion on "Applications of Method Study to Industry," 2.30 p.m.

Thurs., Feb. 19.—NORTH-WESTERN SECTION: Blossoms Hotel, Chester, "Liquid Fuels and Appliances for Domestic Heating," S. S. Whitehead, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Feb. 17.—NORTHERN IRELAND PANEL: College of Technology, Belfast, "Metallurgy in Marine Engineering," J. E. Garside, 7.30 p.m.

Thurs., Feb. 19.—KINGSTON UPON HULL AND EAST MIDLANDS SECTION: College of Technology, Park Street, Kingston upon Hull, "The Junior Engineer's First Trip to Sea," H. C. Gibson, 7.30 p.m. ★ WEST MIDLANDS SECTION: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, Annual General Meeting; "Marine Machinery Breakdowns," J. H. Milton, 6.30 p.m. ★ NORTH-EAST COAST SECTION: Stephenson Building, King's College, Claremont Road, Newcastle upon Tyne, Annual General Meeting, "Heavy Oil Burning," J. S. Clarke, 6.15 p.m. ★ SOUTHERN JOINT BRANCH: College of Technology, Portsmouth, Joint Meeting with the Institution of Naval Architects, "Some Interesting Aspects of Model Test Work," W. A. Crago, 7.30 p.m.

Fri., Feb. 20.—SOUTH WALES SECTION: South Wales Institute of Engineers, Park Place, Cardiff, "Nuclear Steam Propulsion for Merchant Ships," W. B. Wootton, 7 p.m.

INSTITUTE OF NAVIGATION

Fri., Feb. 20.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Meteorological Briefing Information," D. McNaughton, 5.15 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, Feb. 13.—SOUTH WALES CENTRE: South Wales Institute of Engineers, Park Place, Cardiff, "Recent Developments in Fuel Injection Pump Design," W. E. Hatherill, 7 p.m.

Mon., Feb. 16.—SCOTTISH CENTRE: North British Hotel, Princes Street, Edinburgh, "Transport Development in U.S.A.," J. F. Moon, 7.30 p.m. ★ EAST REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "Servicing of Electrical Equipment," H. J. Stoneman, 7.45 p.m.

Tues., Feb. 17.—WEST REGIONAL CENTRE: Liverpool Architectural Society's Rooms, Bluecoat Chambers, School Lane, Liverpool, 1, "The 'N' Type Injection Pump and Hydraulic Governor," P. Bullock, 7.30 p.m. ★ NORTH EASTERN CENTRE: Three Tuns Hotel, Durham City, "Transport Development in U.S.A.," J. F. Moon, 7.30 p.m.

Thurs., Feb. 19.—METROPOLITAN AREA: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "Research on the Testing and Performance of Commercial Vehicle Brakes," H. J. H. Starks, 6.30 p.m. ★ YORKSHIRE CENTRE: Great Northern Hotel, Wellington Street, Leeds, 1, "Disc Brakes and Independent Suspensions," J. Pearson, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Feb. 17.—LONDON BRANCH: 6, Buckingham Gate, London, S.W.1, "The Application of Electricity to Agriculture," P. G. Finn-Kelcey, 2.15 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Feb. 17.—LONDON BRANCH: Great George Street, Westminster, London, S.W.1, "Construction of a Large Experiment Tank at Haslar," J. W. Hunter, A. C. Little and J. D. Hacon, 5.30 p.m.

Wed., Feb. 18.—MIDLANDS ASSOCIATION: Room 129, Civic Centre, Birmingham, "Civil Engineering Sightseeing Abroad," J. B. Menzies, 6 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Feb. 13.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "Some Reasons for Failure in the Part III Examination," opened by M. G. Say, 6 p.m.

Mon. and Tues., Feb. 16 *and* 17.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Discussions on "New Digital-Computer Techniques," 5.30 p.m.

Mon., Feb. 16.—MERSEY AND NORTH WALES CENTRE: Royal Institution, Colquitt Street, Liverpool, "Thermonuclear Processes," D. W. Fry, 6.30 p.m. ★ NORTH-EASTERN RADIO AND MEASUREMENT GROUP: King's College, Newcastle upon Tyne, "A Method of Measuring Self-Inductances Applicable to Large Electrical Machines," J. C. Prescott and A. K. El-Kharashi, 6.15 p.m. ★ NORTH STAFFORDSHIRE SUB-CENTRE: Technical College, Stafford, Discussion on "What is a Cultured Engineer?" opened by K. R. Sturley, 7 p.m. ★ WESTERN SUPPLY GROUP: S.W.E.B. Demonstration Theatre, Electricity House, Colston Avenue, Bristol, 1, "Protection of Rural Networks," F. G. Copland, 6 p.m. ★ HATFIELD DISTRICT BRANCH: Technical College, Hatfield, "Some Problems in the Design of a Missile Guidance System," P. R. Franks, 7 p.m.

Tues., Feb. 17.—LONDON GRADUATE AND STUDENT SECTION: Assembly Hall, 3 (Tels.) Training Bn., R.E.M.E., Arborfield, Berks, "A Survey of Microwave Techniques for the Transmission of Speech and Vision," K. C. Kao, 7 p.m. ★ CAMBRIDGE RADIO AND TELECOMMUNICATION GROUP: Cavendish Laboratory, Free School Lane, Cambridge, "Some Recent Developments in X-Ray and Electron Microscopy," P. Duncumb, 8 p.m. ★ NORTH-WESTERN MEASUREMENT AND CONTROL GROUP: Engineers' Club, Albert Square, Manchester, "A Train Performance Computer," E. Bradshaw, M. Wagstaff and F. Cooke, 6.15 p.m.

Wed., Feb. 18.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "Ultrasonic Iconoscopes," C. N. Smyth, and J. Sayers, 5.30 p.m. ★ NORTH-EASTERN CENTRE: Literary and Philosophical Society, Newcastle upon Tyne, First Hunter Memorial Lecture, "P. V. Hunter—Electrical Engineering in our Time," C. O. Boyse, 6.15 p.m. ★ SHEFFIELD SUB-CENTRE: Grand Hotel, Sheffield, "Electrification of the U.K.A.E.A. Industrial Group Factories," J. W. Binns and W. J. Outram, 6.30 p.m. ★ SOUTHERN CENTRE: C.E.G.B. Offices, 111, High Street, Portsmouth, "G.P.O. Television Links," T. Kilvington, 6.30 p.m.

Thurs., Feb. 19.—IRISH BRANCH: Physical Laboratory, Trinity College, Dublin, "Appraisal of the Factors Appertaining to Reliable Television and V.H.F. Coverage," N. W. Mulcahy, 6 p.m.

Fri., Feb. 20.—RADIO AND MEASUREMENT SECTIONS: Savoy Place, London, W.C.2, "The Measurement of Errors in Data Transmission for the Design of Detecting and Correcting Equipment," V. J. Terry and E. D. G. Wright, 5.30 p.m. ★ SOUTHERN CENTRE: S.E.B. Showrooms, Newport, Isle of Wight, "Installation of a B.B.C. Television Transmission Station," E. P. Metcalf, 6.30 p.m.

INSTITUTION OF ENGINEERS IN CHARGE

Wed., Feb. 18.—Kent Room, Caxton Hall, London, S.W.1, "Air Conditioning," H. J. G. R. Strudwick, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Feb. 18.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Some Design Considerations of Main Line Diesel Locomotives," T. Schur, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Feb. 13.—ORDINARY MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Induction Ramming of Small High-speed Air Compressor," F. K. Bannister, 6 p.m. ★ SCOTTISH BRANCH: Robert Gordon's College, Aberdeen, "Some Engineering Aspects of Nuclear Energy Developments," A. T. Bowden, 7.30 p.m.

Mon., Feb. 16.—DERBY A.D. CENTRE: Midland Hotel, Derby, "Design Features of Wheeled Fighting Vehicles," C. W. Sewell, 7.15 p.m. ★ SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, Glasgow, "Fatigue Testing in Vehicle Components," T. C. F. Stott; Annual Meeting, 7.30 p.m.

Tues., Feb. 17.—HYDRAULICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Pumping of Liquids of Unusual Viscosity, Volatility, or Solid or Gas Content," 6 p.m. ★ SOUTH WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Noise and Hearing: Physiological Aspects," W. Burns, and "Origins of Diesel Engine Noise," A. E. W. Austen and T. Priede, 6 p.m. ★ WESTERN BRANCH: Engineering Laboratories, The University, Bristol, "Mechanical Marshalling of Railway Wagons in Works Sidings," G. W. Grossmith, 7 p.m. ★ COVENTRY A.D. GRADUATES' SECTION: Wine Lodge, Burges, Coventry, "Interior Space Problems in Vehicle Design," B. C. Mills, 7.30 p.m. ★ EAST MIDLANDS GRADUATES' SECTION: Technical College, Lincoln, "Water Lubricated Bearings," R. Holmes, 7.15 p.m.

Wed., Feb. 18.—SOUTHERN BRANCH: College of Technology, Anglesea Road, Portsmouth, "Some Experiments with Internal Combustion Engines," R. C. Cross, 6.30 p.m. ★ YORKSHIRE BRANCH: Royal Station Hotel, Hull, "Recent Developments in Propulsion Machinery and Refrigeration Equipment for Deep Sea Trawlers," G. C. Eddie, 7.30 p.m. ★ NORTH EASTERN A.D. CENTRE: New Chemistry Theatre, The University, Leeds, "Corrosion Prevention in Vehicle Bodies," T. P. Hoare, 7.30 p.m. ★ NORTH EASTERN GRADUATES' SECTION: Vane Arms, Stockton, "Air Conditioning with Special Reference to Self-Contained Air Conditioners," H. Pollak, 7 p.m. ★ SOUTHERN GRADUATES' SECTION: Cockcroft Hall, Harwell, "Interplanetary Travel," Dr. Sheppard, 3.15 p.m.

Thurs., Feb. 19.—NORTH WESTERN A.D. CENTRE: Engineers' Club, Manchester, Annual Meeting; "Years of Development," R. A. Wilson-Jones, 7 p.m. ★ LONDON GRADUATES' SECTION: 1, Birdcage Walk, Westminster, London, S.W.1, "Gyroscopes in Automatic Controls," T. N. Dewey and J. E. Stephenson, 6.30 p.m. ★ SOUTHERN GRADUATES' SECTION: Technical College, Southampton, Film Show, 7.30 p.m. ★ YORKSHIRE GRADUATES' SECTION: Hotel Metropole, Leeds, Chairman's Address, 6.30 p.m.

Fri., Feb. 20.—ORDINARY MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Experimental Study of Some Variables of the Tube Expanding Process," L. E. Culver and Hugh Ford, 6 p.m. ★ MIDLAND GRADUATES' SECTION: Visit to Tubes, Ltd., Rocky Lane, Aston, Birmingham, 7 p.m.

Sat., Feb. 21.—EASTERN GRADUATES' SECTION: Visit to *News of the World*, 7 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., Feb. 16.—NORTHERN REGION: Rutherford College of Technology, Northumberland Road, Newcastle upon Tyne, "Practical Application of Production Engineering Research," D. F. Galloway, 7 p.m.

Tues., Feb. 17.—SOUTHERN REGION: Town Hall, Oxford, "Machine Tools," 7.30 p.m.

Wed., Feb. 18.—EAST AND WEST RIDINGS REGION: Technical College, Huddersfield, Films, 7.30 p.m.; Annual General Meeting, 8.15 p.m. ★ MIDLANDS REGION: James Watt Memorial Institute, Great Charles Street, Birmingham, "New Materials—New Techniques—They Challenge the Production Engineer," D. Wragge Morley, 7 p.m. ★ WOLVERHAMPTON GRADUATE SECTION: Wolverhampton and Staffs College of Technology, Wulfruna Street, Wolverhampton, "A.B.C. of Machine Tool Control," M. G. Page, 7 p.m. ★ NORTH MIDLANDS REGION: Conference Room, Peterscourt, Peterborough, "Production Control—Works Management Viewpoint," L. P. Simpson, 7.30 p.m. ★ SCOTTISH REGION: North British Hotel, Princes Street, Edinburgh, "The Production Engineer and Line Management," J. Gloag, 7.30 p.m. ★ WALES REGION: Central Library, Swansea, "Unconventional Tooling," S. E. Kirk, 7 p.m.

Thurs., Feb. 19.—NORTHERN IRELAND REGION: Kensington Hotel, College Square East, Belfast, Presidential Address, The Rt. Hon. The Earl of Halsbury, 7.30 p.m. ★ SCOTTISH REGION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Some Problems Associated with the Selections of Machine Tools for Heavy Engineering Production," J. Henderson, 7.30 p.m. ★ SOUTH EASTERN REGION: Royal Empire Society, Northumberland Avenue, London, W.C.2, "Planned Maintenance of Electrical and Mechanical Equipment in a Paper Mill," C. A. Castle, and D. W. Bexton, 7 p.m. ★ SOUTHERN REGION: Polygon Hotel, Southampton, "Manufacture and Application of Junction Transistors," E. Walfendale, 7.15 p.m.

Fri., Feb. 20.—SOUTH WESTERN REGION: Technical College, Brunswick Road, Gloucester, "Fine Measurements," J. C. Evans, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Feb. 13.—MIDLAND COUNTIES BRANCH (GRADUATES AND STUDENTS SECTION): Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Safety in Erection of Structural Steelwork," H. E. Dyble, 6.30 p.m.

Wed., Feb. 18.—YORKSHIRE BRANCH: Metropole Hotel, Leeds, "Design and Construction Problems Involved in High Point Construction," G. W. Kirkland and D. Marriott, 6.30 p.m.

Fri., Feb. 20.—SCOTTISH BRANCH: Institution of Engineers and Shipbuilders, Glasgow, "Modern Trends in the Design of Steel Bridges and Structures," W. R. Cox, 7 p.m.

INSTITUTION OF WATER ENGINEERS

Wed., Feb. 18.—SOUTH EASTERN SECTION: Institution of Civil Engineers, Great George Street, London, S.W.1, Films, 2.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Feb. 13.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Energy Demands in Britain and a Fuel Policy," J. G. King, 7 p.m.

Fri., Feb. 20.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Selection and Use of Arc Welding Processes," E. Flintham, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Feb. 13.—Engineers' Club, Albert Square, Manchester, 2, "Marine Salvage and Salvage of 'Empress of Canada,'" W. R. Colbeck, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Feb. 13.—Lecture Theatre, Mining Institute, Neville Hall, Newcastle upon Tyne, "The Manufacture of Marine Oil Engines," J. E. Smith, 6.15 p.m.

PLASTICS INSTITUTE

Tues., Feb. 17.—Wellcome Building, 183–193, Euston Road, London, N.W.1, "Sources of Raw Materials for the Plastics Industry," A. W. C. Taylor, 6.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., Feb. 18.—11, Upper Belgrave Street, London, S.W.1, "Vibration Control in Piling and Blasting," J. H. A. Crockett, 6 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Tues., Feb. 17.—12, Great George Street, London, S.W.1, "Managing the Nation's Houses," L. G. Brooks, 5.45 p.m.

ROYAL STATISTICAL SOCIETY

Wed., Feb. 18.—London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "The Comparison of Survival Curves," P. Armitage, 5.15 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon. Feb. 16.—The University Building, St. George's Square, Sheffield, "Automatic Press Forging," J. G. Wistretch and J. D. Stringer, 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Thurs., Feb. 19.—ROAD AND BUILDING MATERIALS GROUP: 14, Belgrave Square, London, S.W.1, "Paint and Paint Films as Chemical and Physical Structures," S. H. Bell, 6 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Mon., Feb. 16.—Rotunda, Cheltenham, "Instruments for Nuclear Reactors," T. D. H. Andrews, 7.30 p.m.

Thurs., Feb. 19.—EAST MIDLAND SECTION: Nottingham and District Technical College, Shakespeare Street, Nottingham, "Data Collection and Processing," 6.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

To-day, Feb. 13.—39, Elmbank Crescent, Glasgow, "Operational Research with Particular Reference to Open-Hearth Charging," R. H. Colcutt, 6.45 p.m.

Advanced Engineering Courses

The Design of Equipment for Human Use. ENGINEERING AND ALLIED EMPLOYERS' WEST OF ENGLAND ASSOCIATION, Engineers' House, The Promenade, Clifton Down, Bristol. The course is intended for staff concerned with the design of machines and equipment of all kinds which have to be manually operated or controlled. Two weeks' course, Monday, February 16, to Friday, February 27. Fee £40. Accommodation, 25s. per day.

LIFT WITHOUT SLIP with Goodyear rough top conveyor belting

GOODYEAR CONVEYOR BELTING
TYPE. D. ROUGH TOP
A. Thick top cover with deeply impressed gripping pattern.
B. Carcass of 28 or 32 oz. high quality cotton duck.
C. Thickness of hard wearing bottom cover or friction surface to suit service.

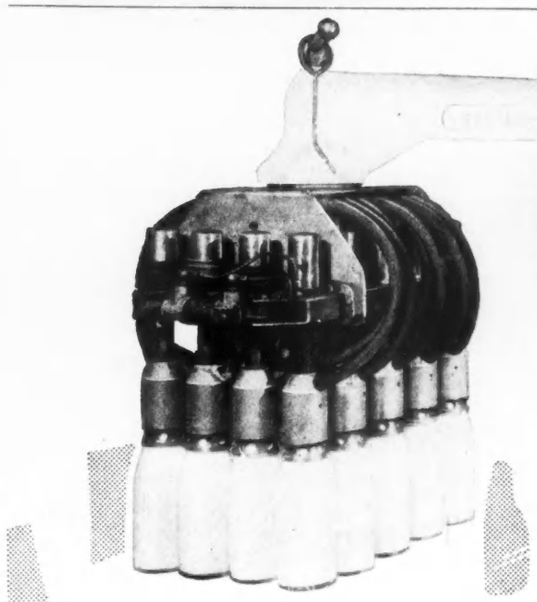
A DEEP REGULAR pattern, exclusive to Goodyear, enables this belting to take a firm grip on sacks and on smooth articles, such as cartons. The pattern, plus a choice between soft and hard top cover to suit the needs of the installation, ensures freedom from slip on slopes up to 30° inclination.

Goodyear Rough Top belting, like all styles of conveyor belting in the Goodyear range, is solely designed for a specific type of duty, and to give long, reliable service at lowest cost per ton carried.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

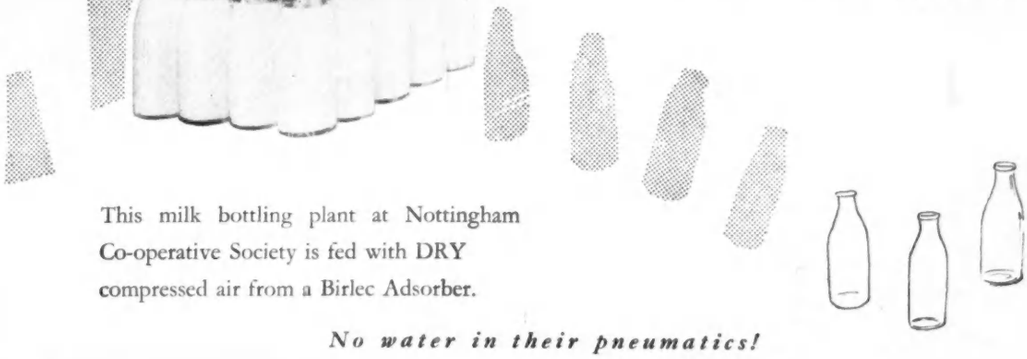
CONVEYOR BELTING · TRANSMISSION BELTING · HOSE · V-BELTS



dry pneumatics

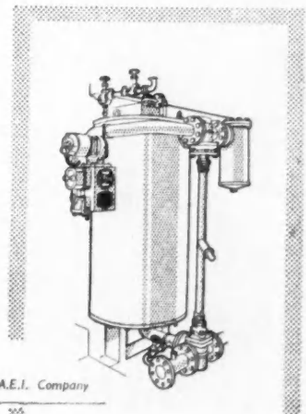
Water vapour is always present in compressed air, building up unseen corrosion, blockages and, finally, expensive maintenance problems.

Birlec Adsorbers banish water worries and problems dry up!



This milk bottling plant at Nottingham Co-operative Society is fed with DRY compressed air from a Birlec Adsorber.

No water in their pneumatics!



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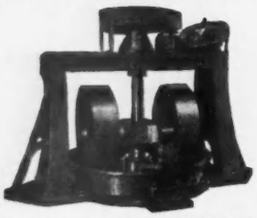

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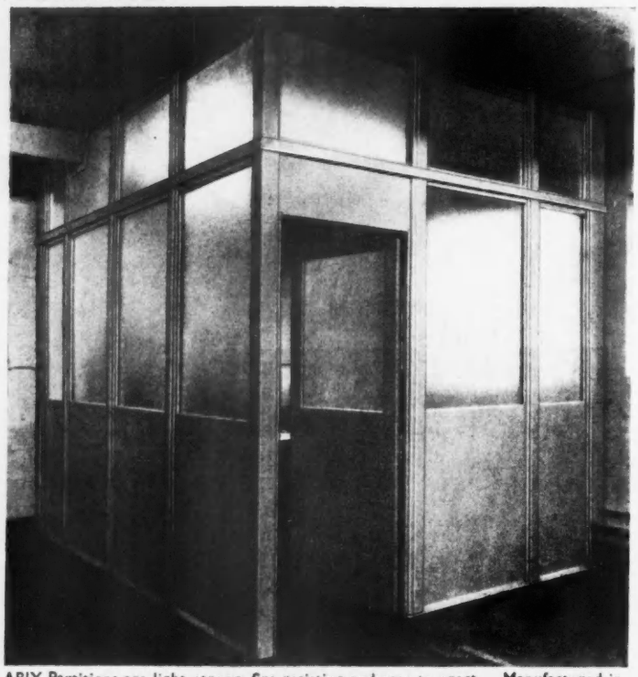

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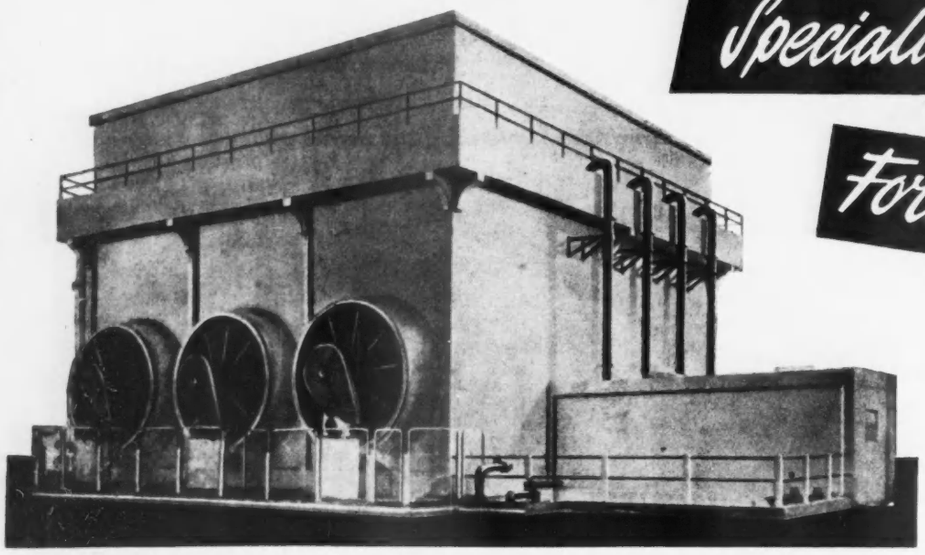

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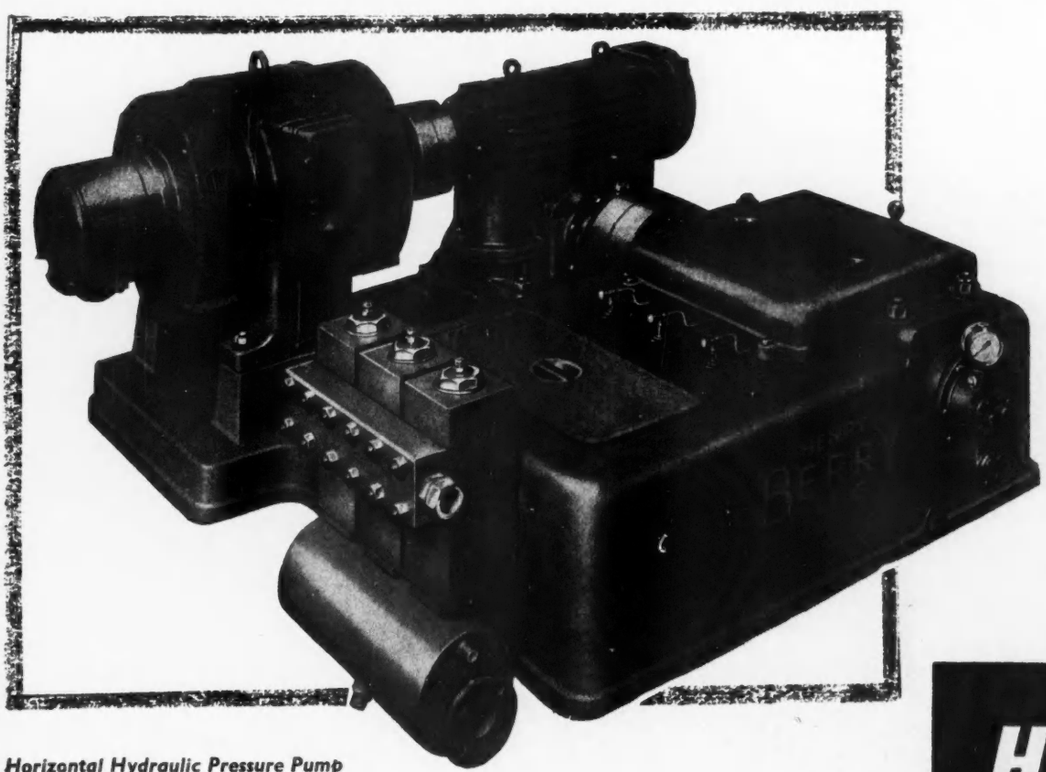

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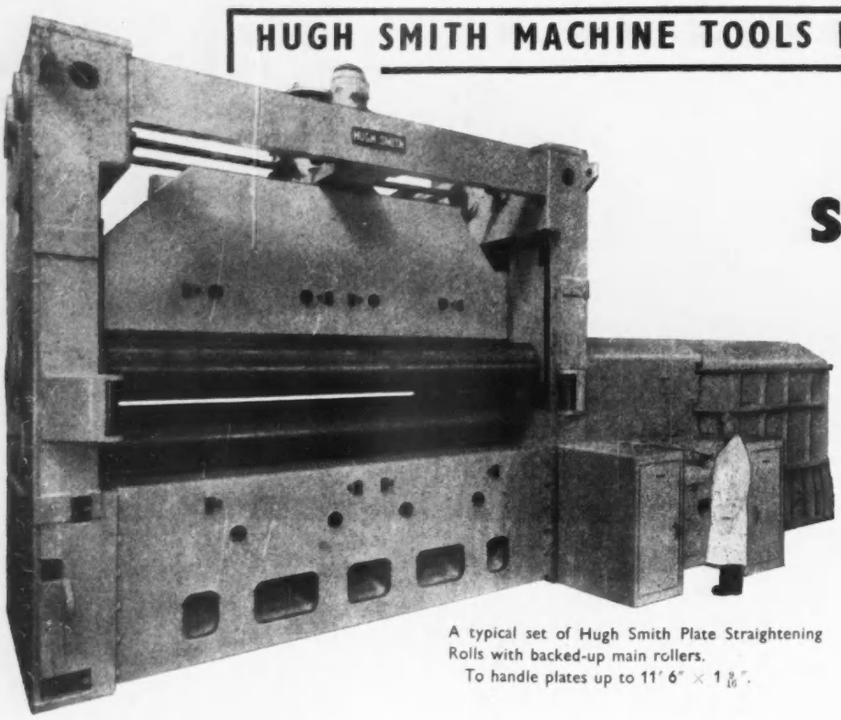

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of modern robust construction suitable for shipyards and structural shops where the continuous production of flat plates is essential.

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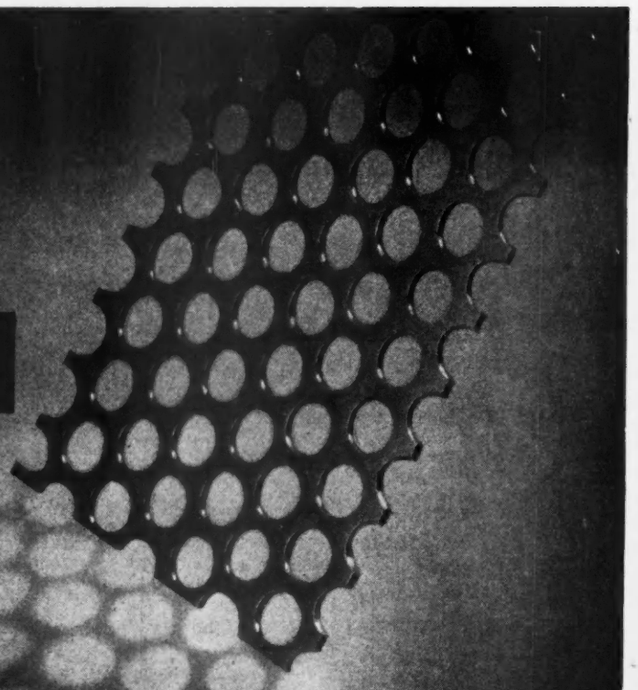

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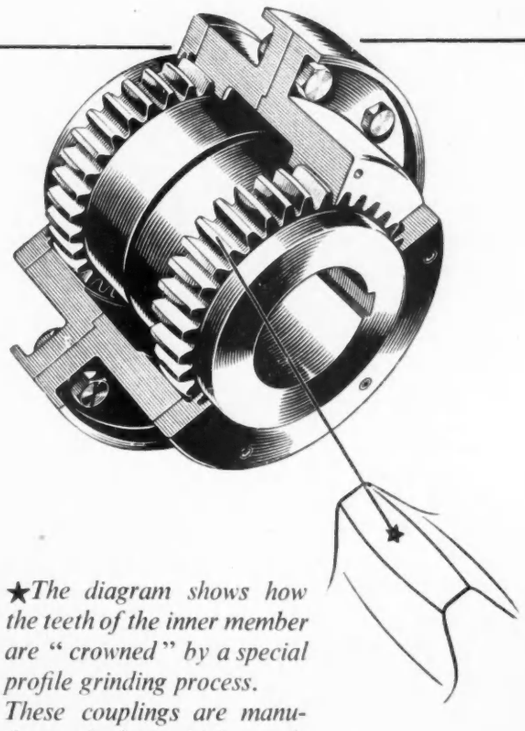
a gear type coupling



★*The diagram shows how the teeth of the inner member are "crowned" by a special profile grinding process. These couplings are manufactured from high grade steel, in eleven standard sizes, and two types.*

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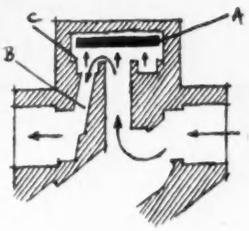
The Spirax 'TD' Trap

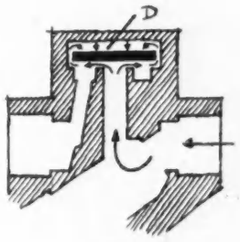
— how it works



Disc A is raised from seat by incoming pressure, allowing instant discharge of air and condensate through outlet B.

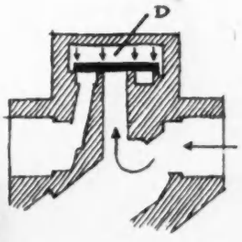
★

High velocity of following steam creates a low pressure area under disc and builds up pressure in chamber D.



★

Steam pressure in chamber D exceeds combined force of the incoming steam and the low pressure area. Acting on full top area of the disc, it forces it down and closes the inlet. On no load the valve is thus closed tight.



and how it works!

The Spirax ½ inch 'TD' is all stainless steel with only one moving part. It works in any position, up to 550°F and without adjustment from 10–350 psi. It has remarkable discharge capacities and is unaffected by superheat, waterhammer, vibration, corrosive condensate and freezing.

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Please post full details of the new Spirax Thermodynamic Trap.

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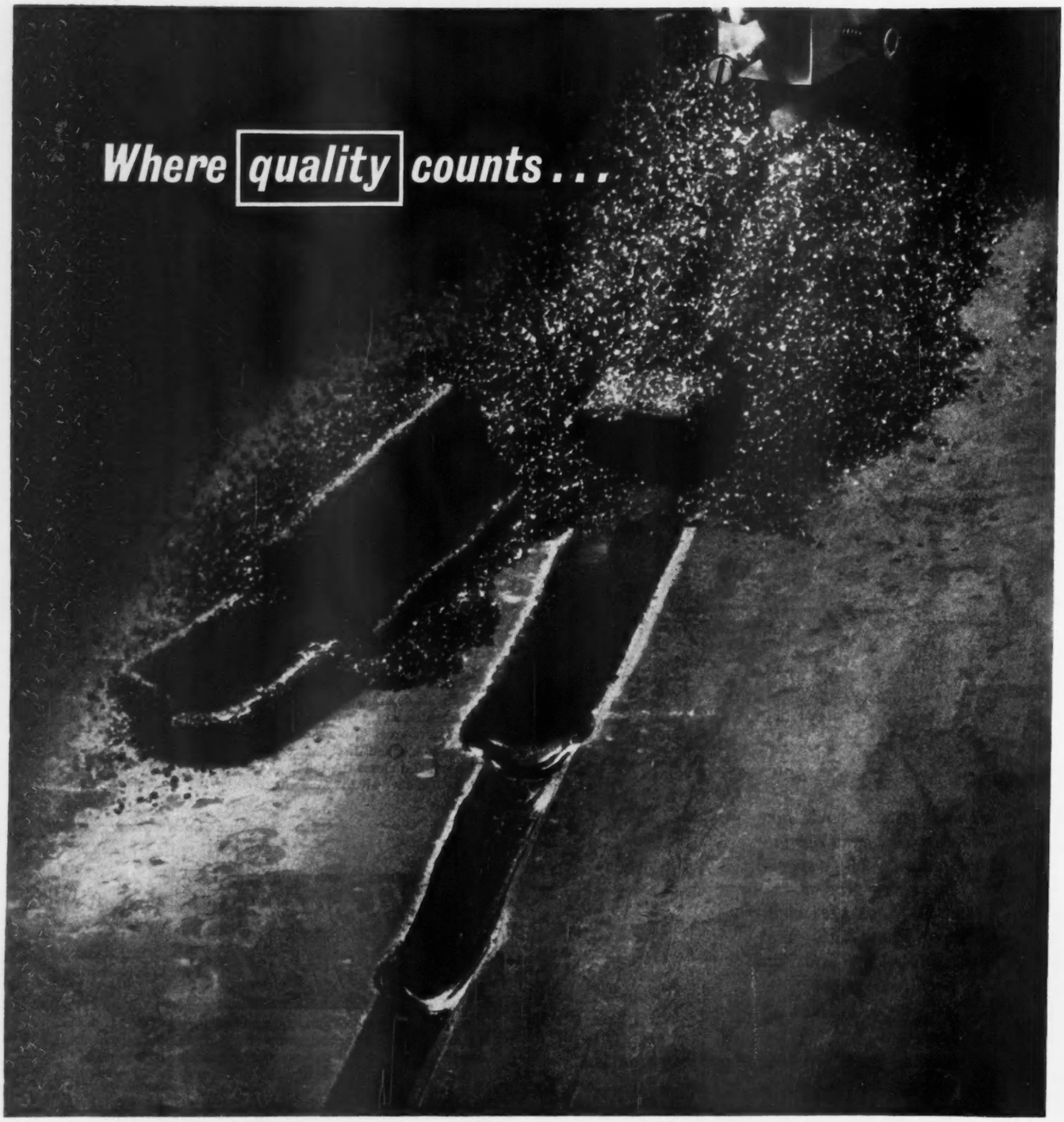

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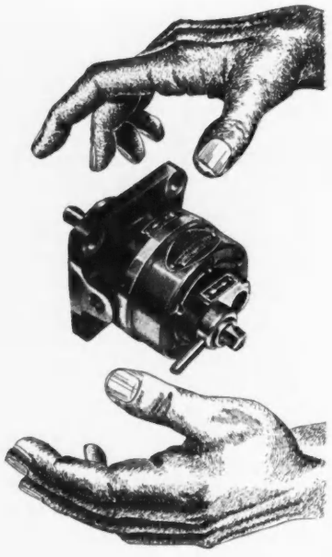

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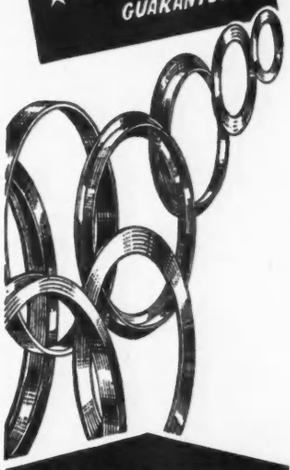

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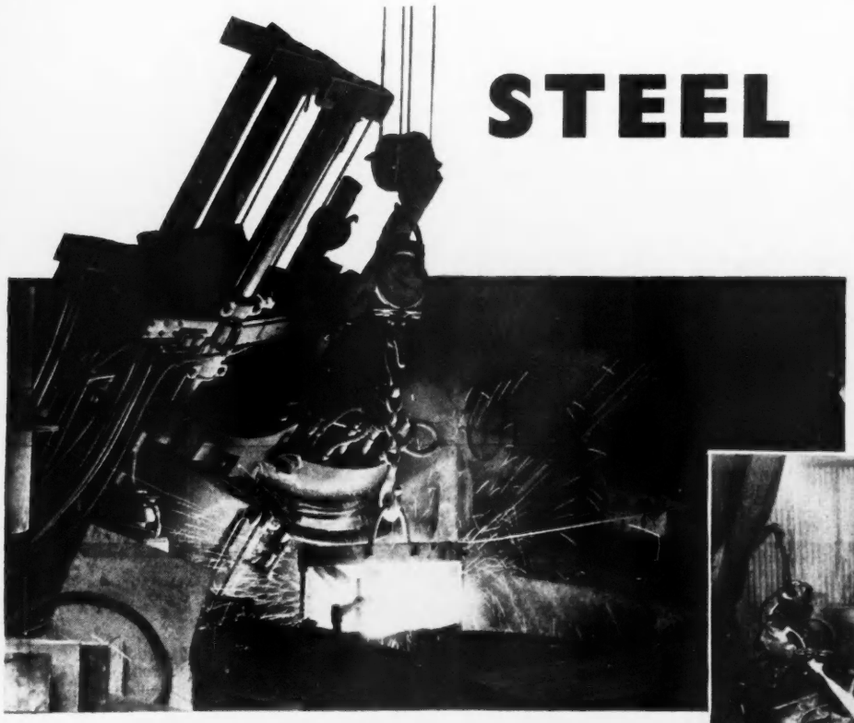

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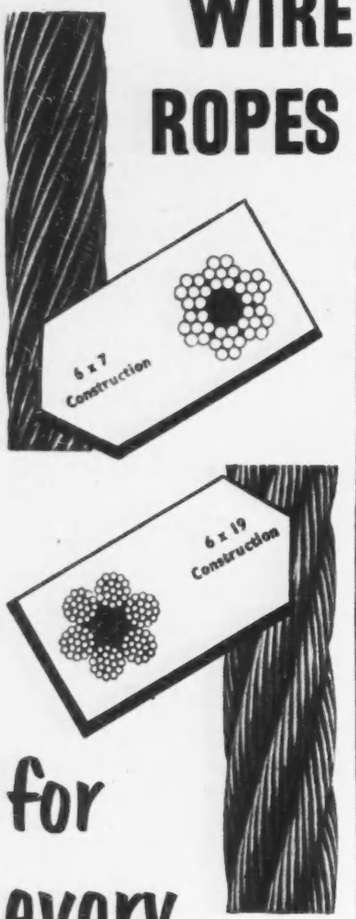
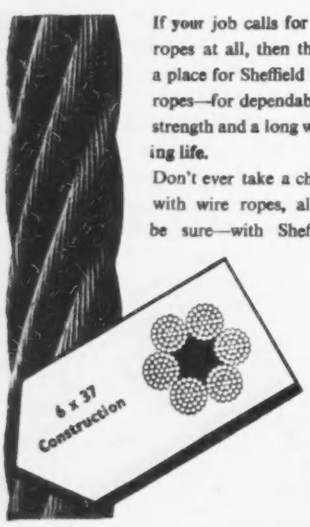


for every purpose



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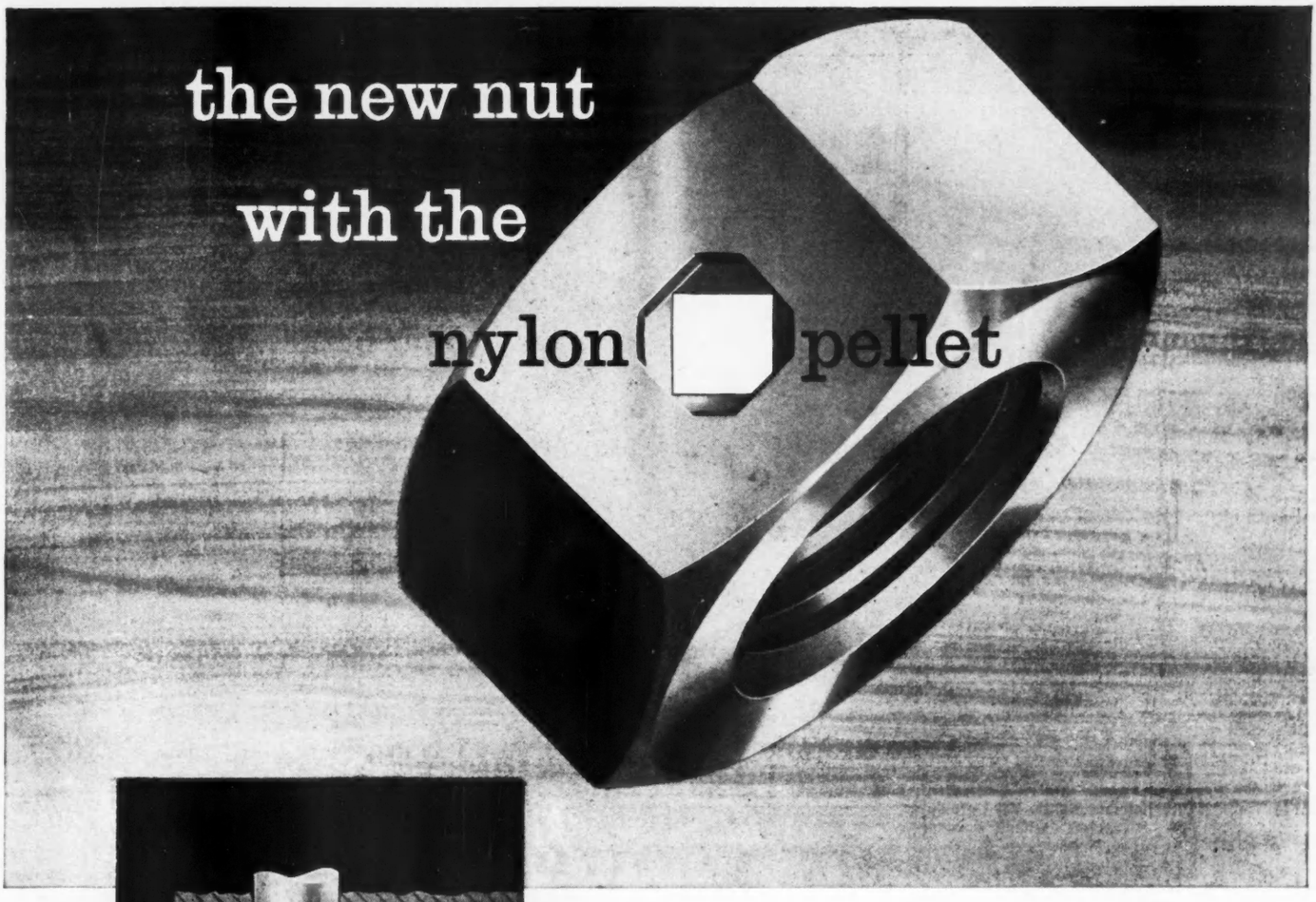

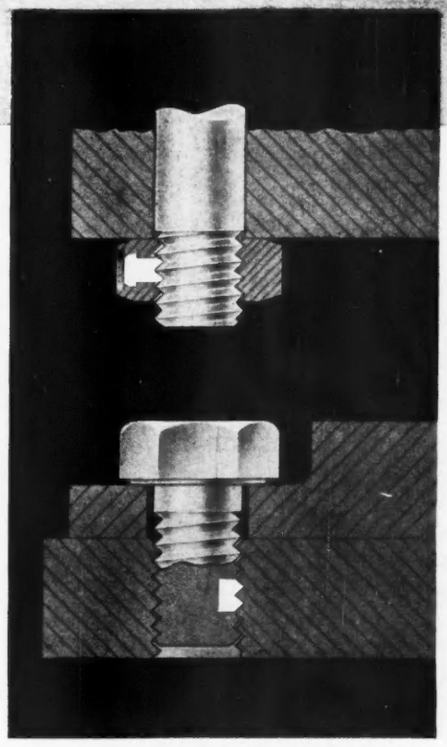

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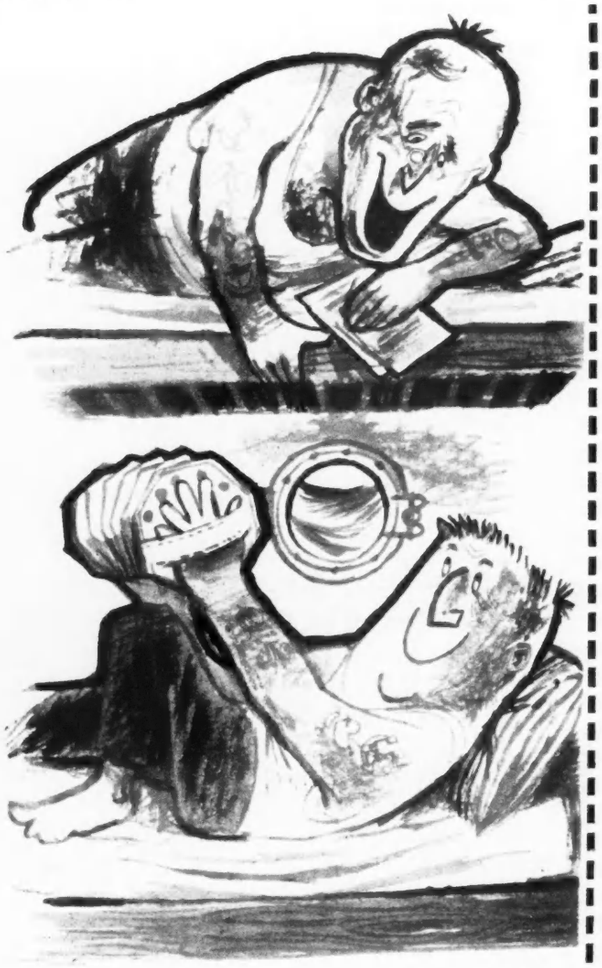

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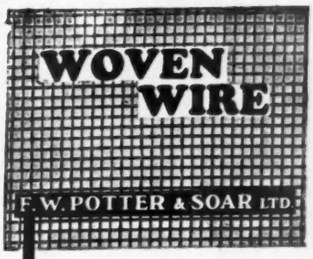

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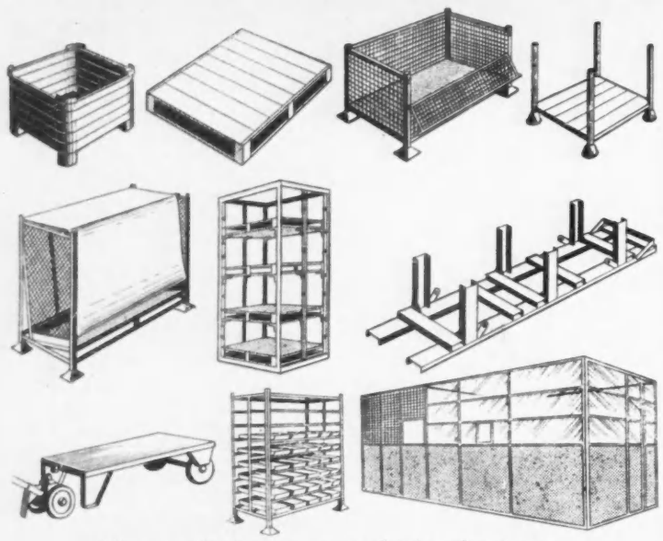

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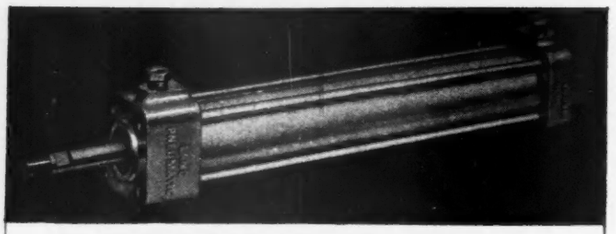

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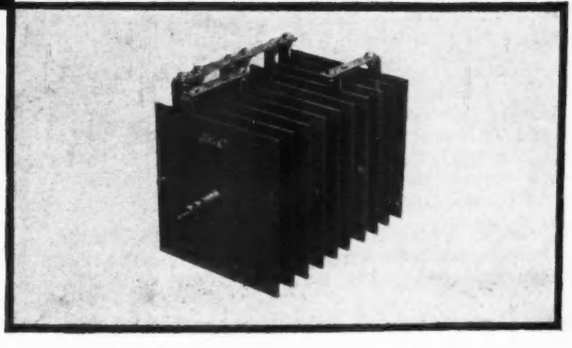
Like all germanium rectifiers in the G.E.C. range, the GEX 541 offers low forward resistance and corresponding increases in efficiency and regulation.

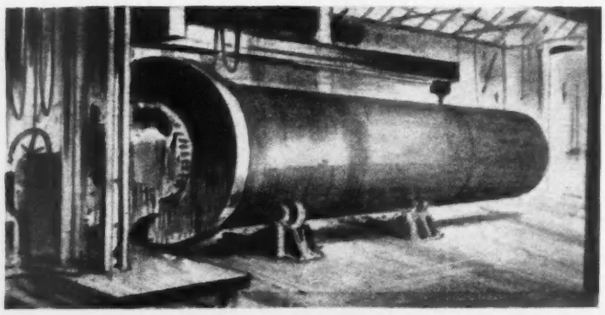
THE BASIC GEX 541 is a germanium junction diode. Single units are available for such applications as DC blocking and gating. Complete rectifier stacks can be supplied, finned or unfinned, suitable for currents up to 160 amps. or D.C. output voltage of up to 900 volts.

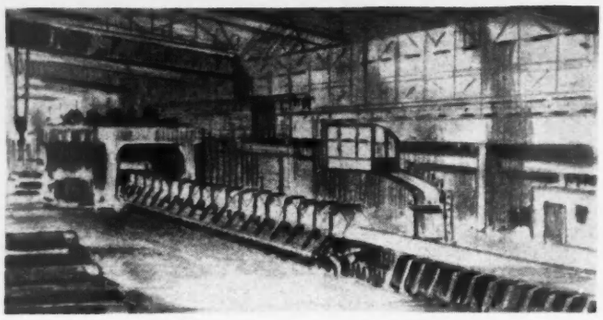


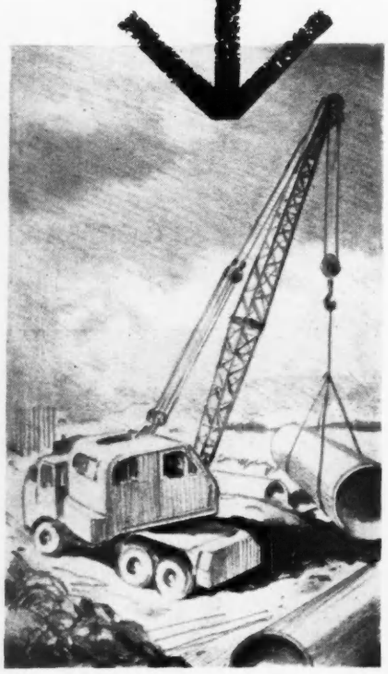
For Data Sheets and further information please write to the Valve and Electronics Dept.

THE GENERAL ELECTRIC COMPANY LIMITED
MAGNET HOUSE · KINGSWAY · LONDON WC2

If your problem is tilting moments*







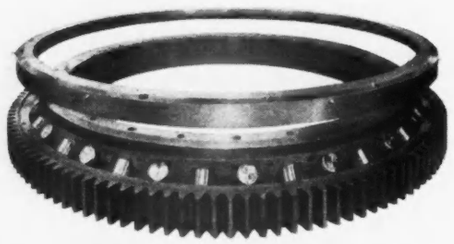
*turn to the Cross-Roll Bearing

Evolved, perfected and manufactured in Great Britain in collaboration with British Timken Limited.

The Priestman Cross-Roll Bearing consists of four separately machined rings. When bolted together in pairs the roller paths form a diamond pattern race section.

The Timken tapered rollers, spaced on the pitch circle by pressed steel cages, alternately contact opposing race surfaces of the outer and inner rings. The crossing of the roller axes in combination with the inclination of the roller paths is the feature that enables the Bearing to resist loads in all directions.

Priestman Cross-Roll Bearings are pre-loaded, pre-lubricated, and sealed self-locating assemblies, requiring no adjustment and little maintenance beyond the periodical replenishment of grease in the labyrinth which supplements the special synthetic rubber cruciform seal, excluding all foreign matter.



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PRIESTMAN BROTHERS LIMITED, HULL, ENGLAND

BCA

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For temporary pipelines 'Unicone' instantaneous joints are recommended. Comprising two parts only, they fasten with a "snap" ensuring a perfect seal in a matter of seconds.

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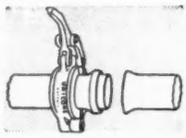
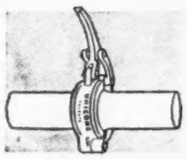
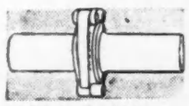

Rubber gasket in position and joint ready to pull over.


Pipe ends joined ready for locking


The completed joint.

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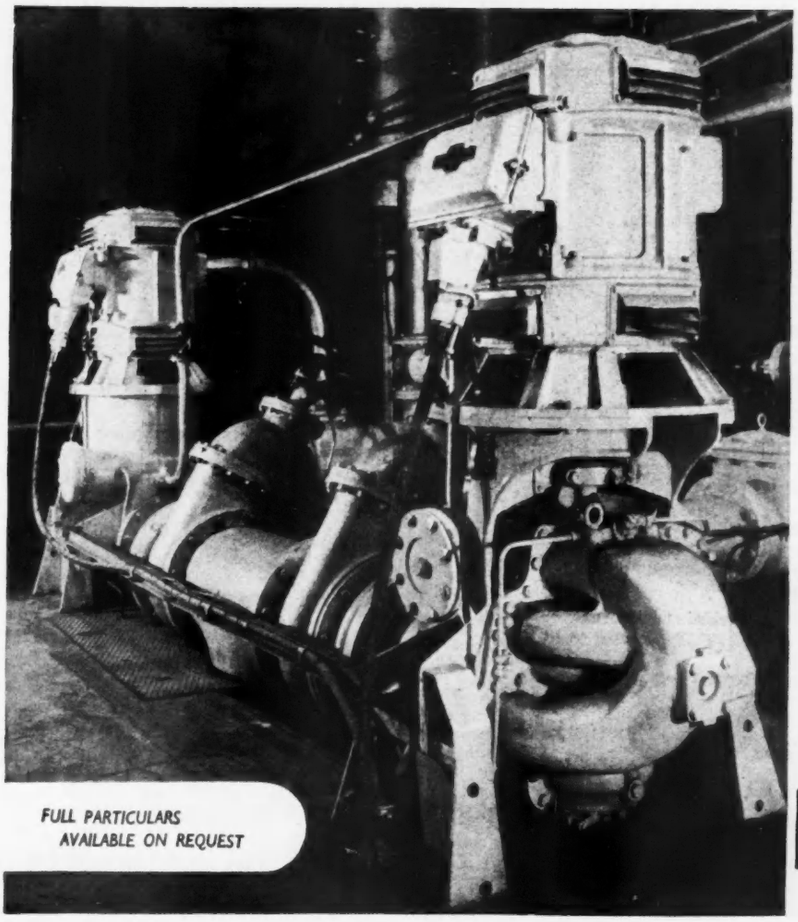

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Extraction Pumps

The Drysdale "Pervac" Pump has been designed for condensate extraction in high vacuum condensing plant where stable operation and high efficiency are fundamental requirements.

The two stage arrangement is eminently suitable for this class of work as the first stage impeller is designed for best possible vacuum, while the second stage impeller deals with external head, and its efficiency is unimpaired by consideration of vacuum.

These pumps are of the Centrifugal Split Casing type and are available in a full range of sizes and capacities in both vertical and horizontal types.

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HEAVY ALUMINIUM AND MILD STEEL

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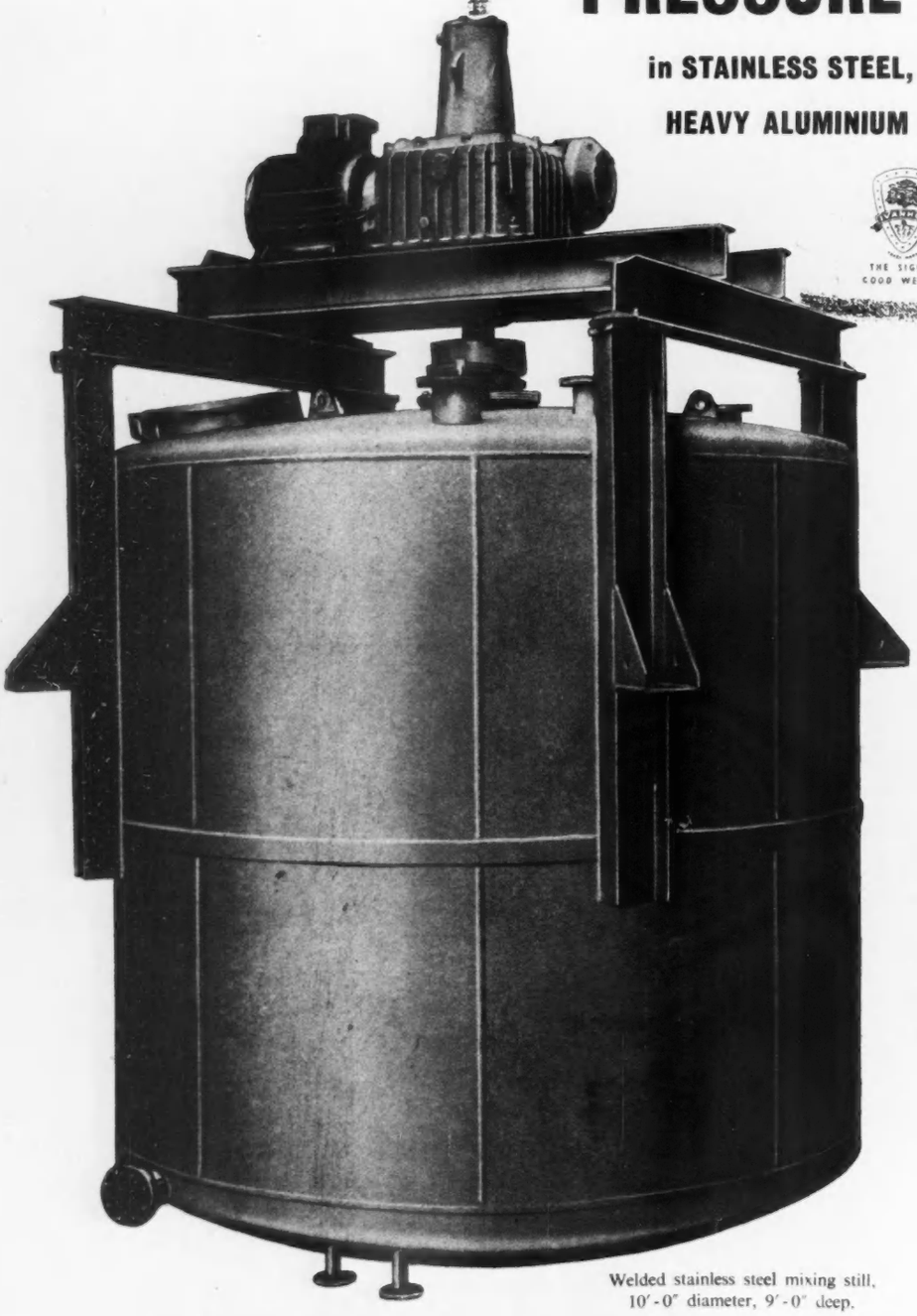

Welded stainless steel mixing still, 10′-0″ diameter, 9′-0″ deep.

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We can now offer a production potential second to none for the fabrication of welded pressure vessels of any size or intricacy of design. We utilise the most advanced welding and inspection control methods and our experience is 100 years young.

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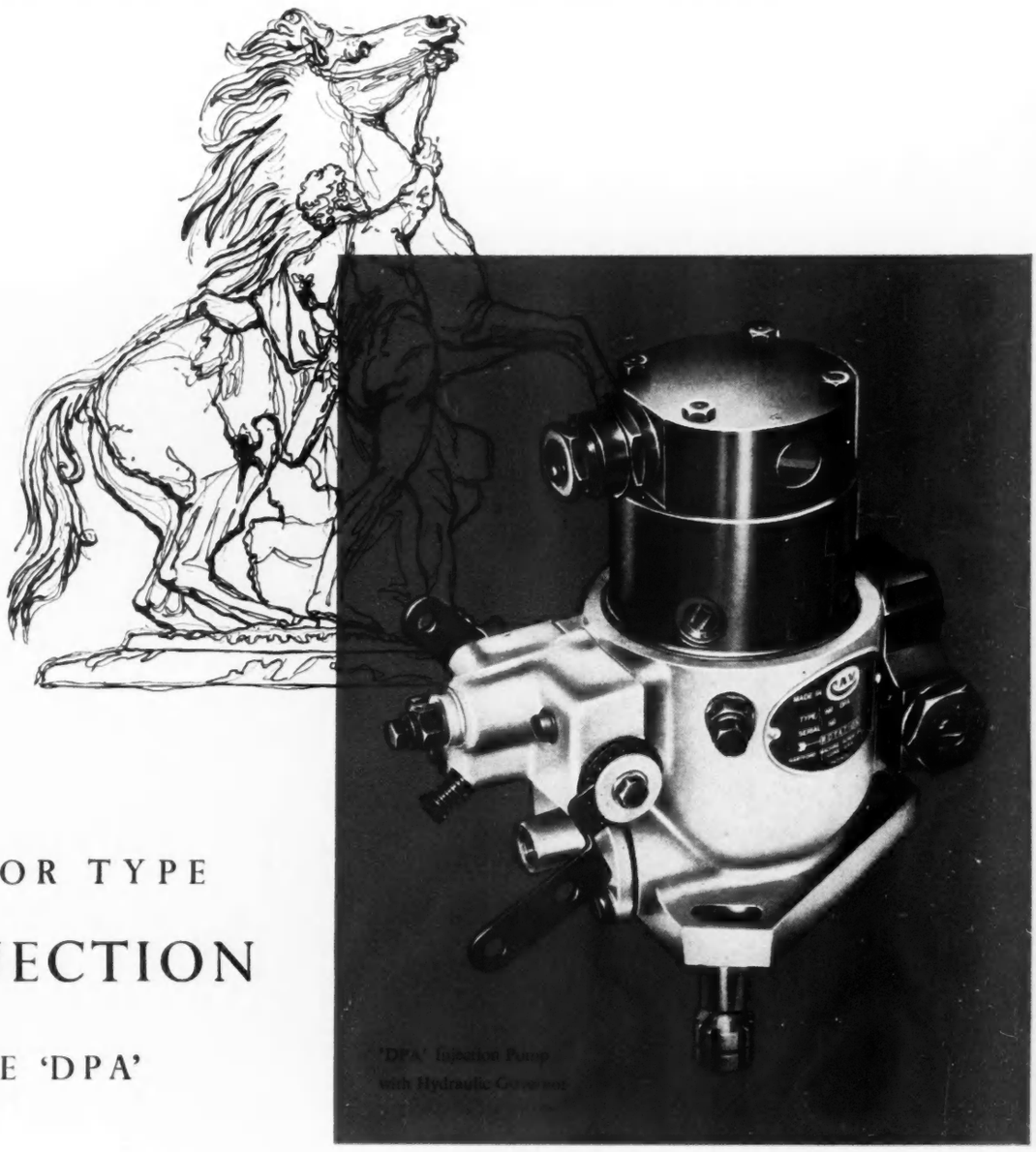

'DPA' Injection Pump with Hydraulic Governor

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PUMP TYPE 'DPA'

The C.A.V. contribution towards the success of the lower-cost modern diesel engine—the 'DPA' pump, developed by C.A.V. research—has rapidly established itself in a premier position, 150,000 having gone into service in the last two years in all parts of the world. Its efficiency has been proved and it is now standard equipment on a number of engines whose names are world famous. The 'DPA' pump offers many advantages—it is simple, light and compact, ideal for installation where space is restricted. It lends itself to the simplest and least expensive form of drive. It is suitable for high speeds, having lightweight parts and no highly stressed springs, and needs no special lubrication. Supplied with simple but extremely effective mechanical or hydraulic governors, giving close speed regulation.

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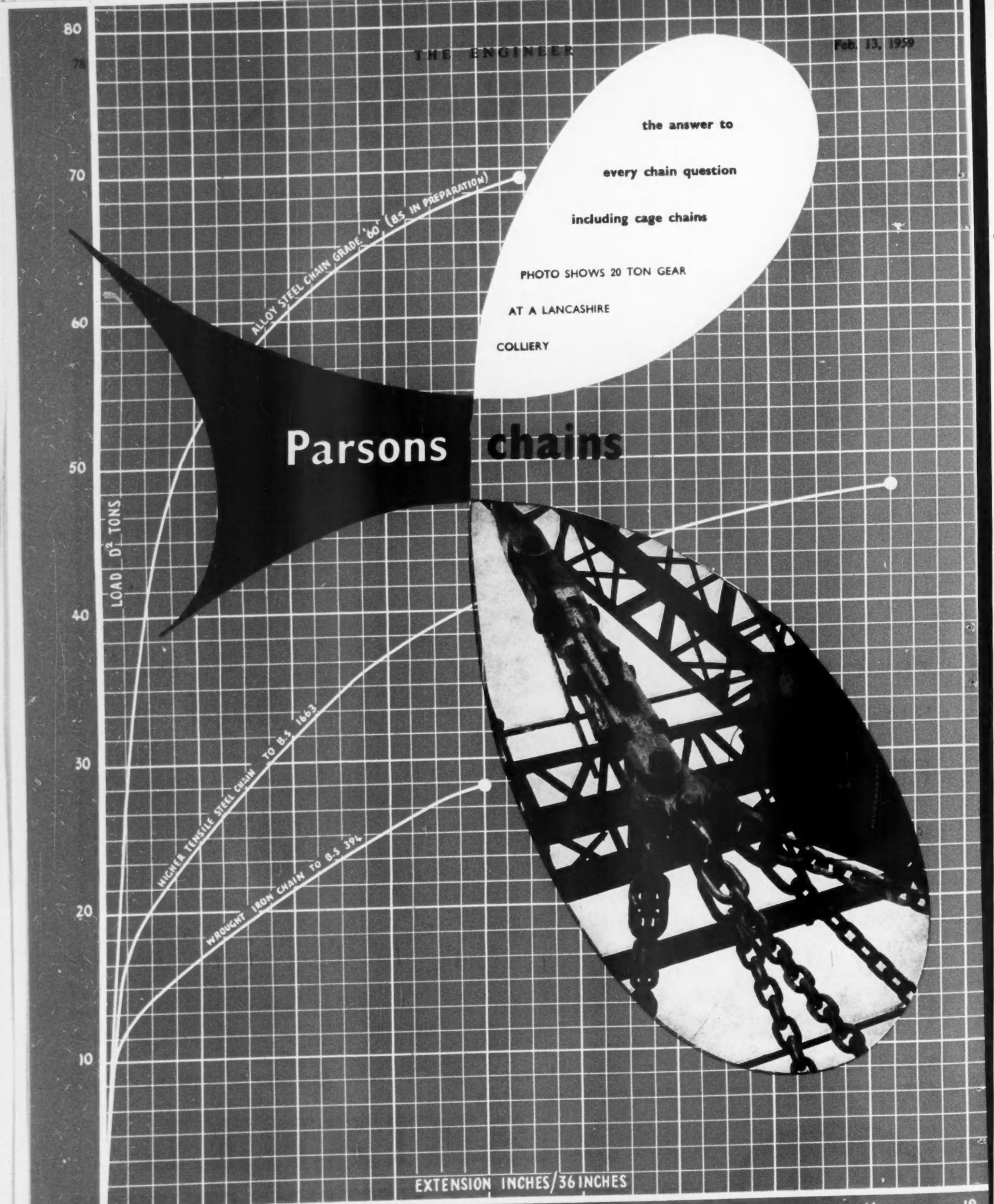

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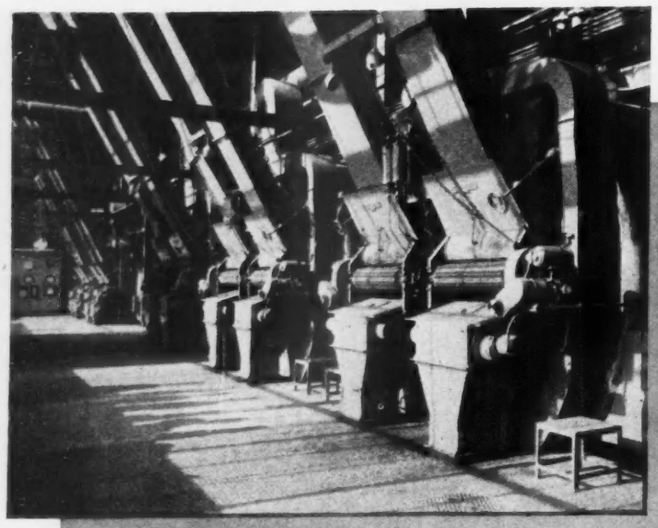

John Thompson Triumph Travelling Grate Stokers and handling plant serving five boilers at Joseph Sankey & Sons Ltd., Bilston. Consulting Engineers for this new boiler plant were Messrs. Powell Duffryn Technical Services Ltd.

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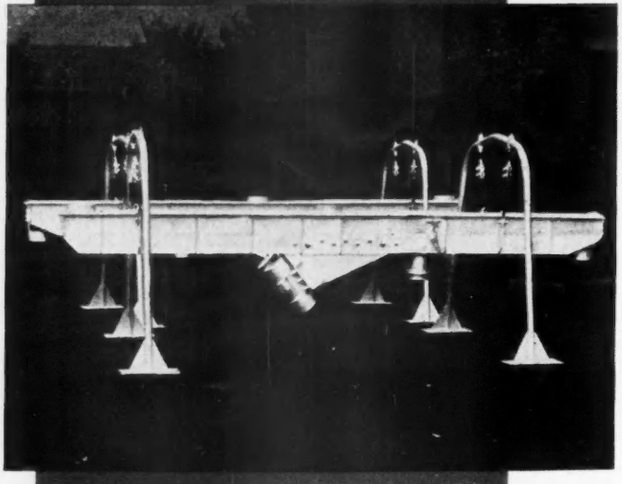

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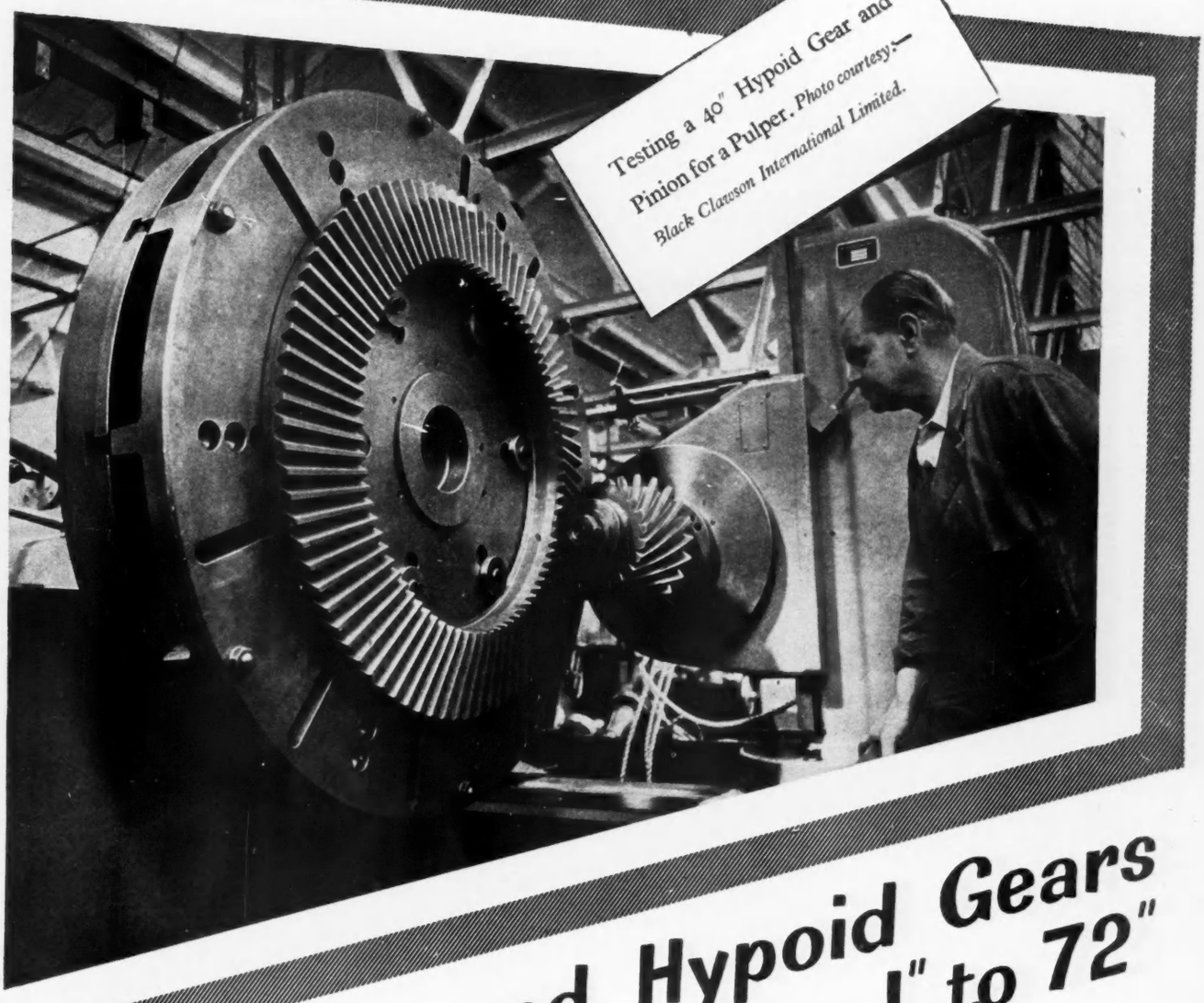

Testing a 40" Hypoid Gear and Pinion for a Pulper. *Photo courtesy:— Black Clawson International Limited.*

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Spiral bevel and hypoid gears offer many advantages for right angle drives where high efficiency and smooth, silent running are required.

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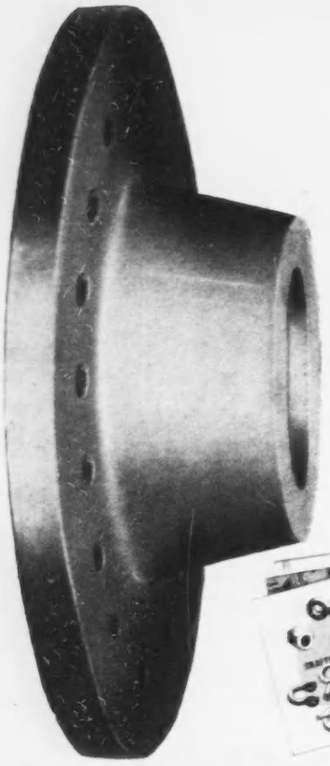

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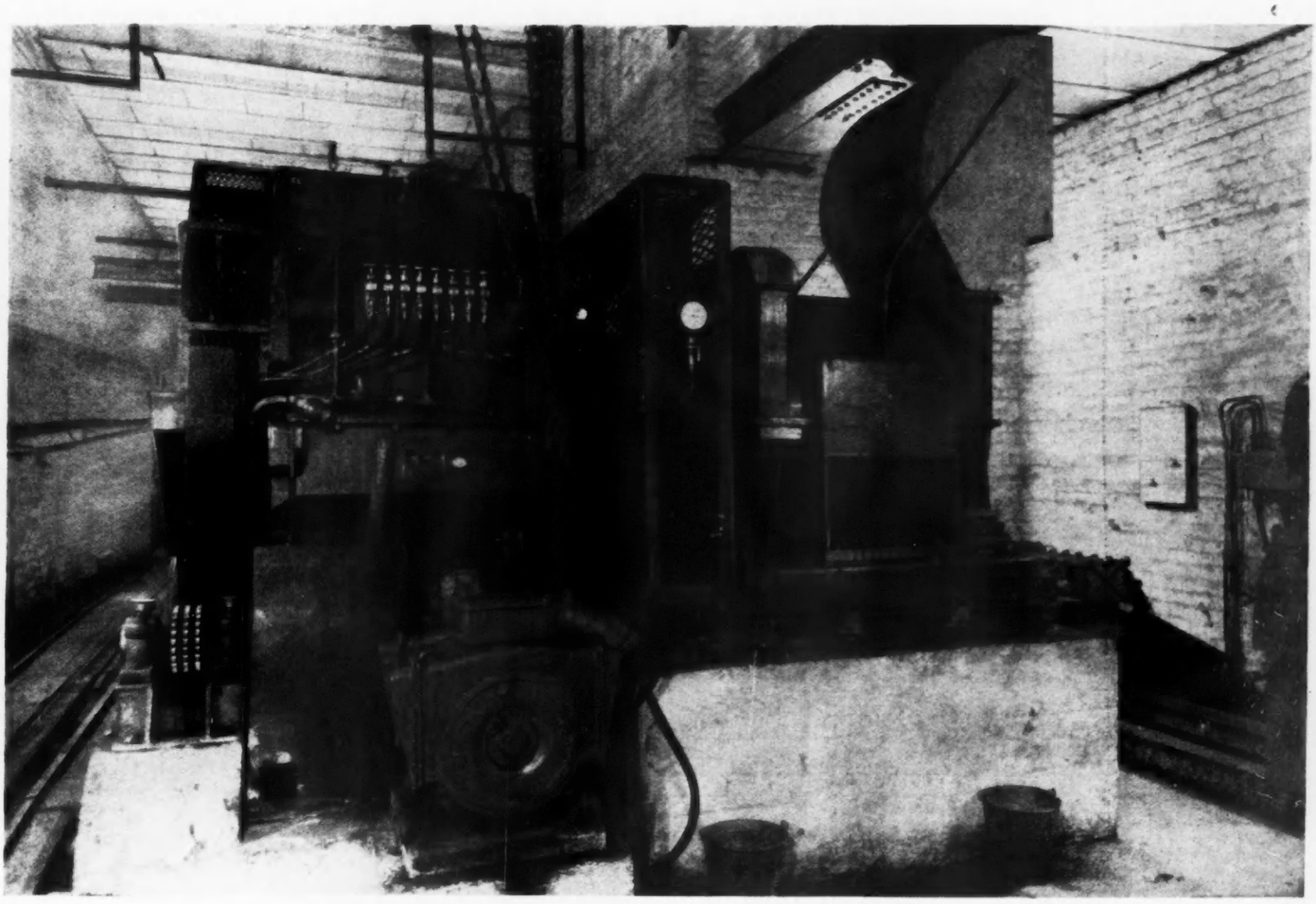

A 330 b.h.p., 3,300 v., 730 r.p.m. Mather and Platt drip proof, double squirrel cage induction motor, with air filter, driving a cable belt conveyor in a coal mine in Scotland. The motor is of the low starting current type arranged for switching direct on the line, taking 3·65 times full load current, and is directly connected to the gearing which drives the cable belt. The small motor in the foreground is for driving at slow speed for rope inspection purposes.

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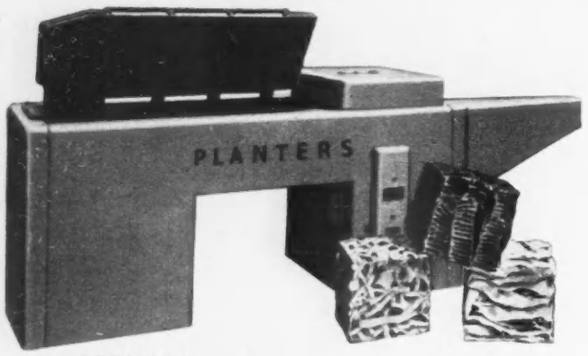

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TUBE
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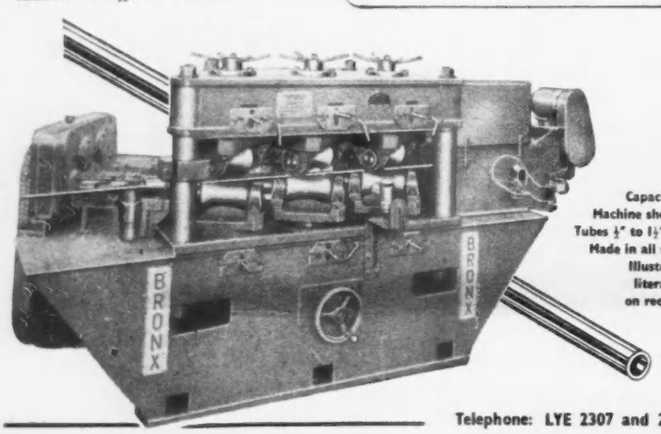

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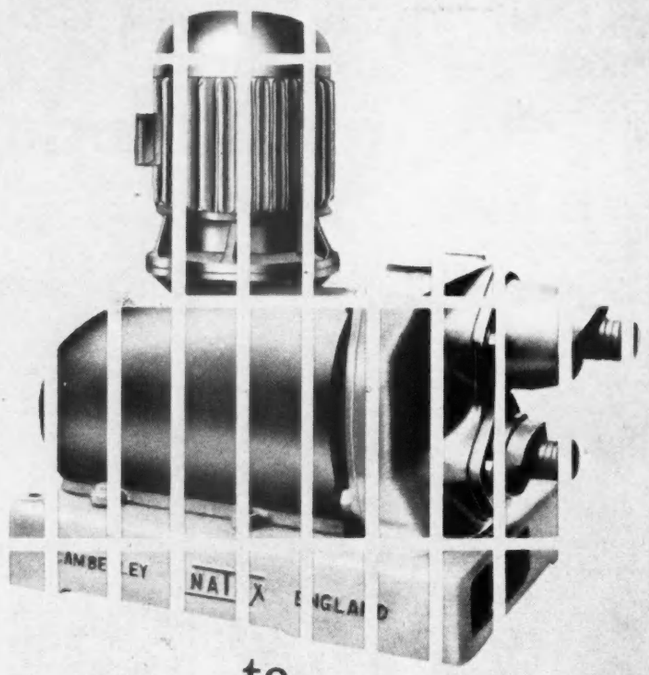

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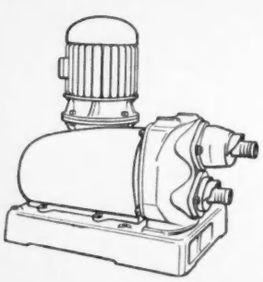
The whole pump body is lined with Linatex rubber using Linatex valves and diaphragm.



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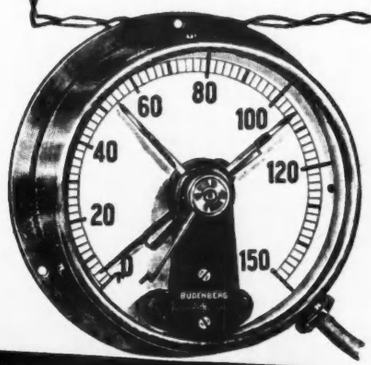
Electric contacts control relays which stop and start motors at pressures or temperatures which can be individually and accurately set. Intrinsically safe and flame-proof schemes are available. Please send for Catalogue Section 1D.



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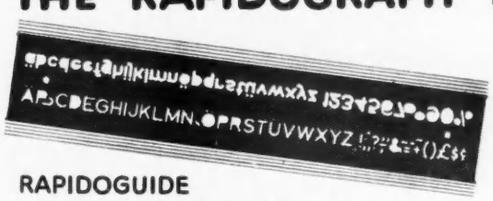

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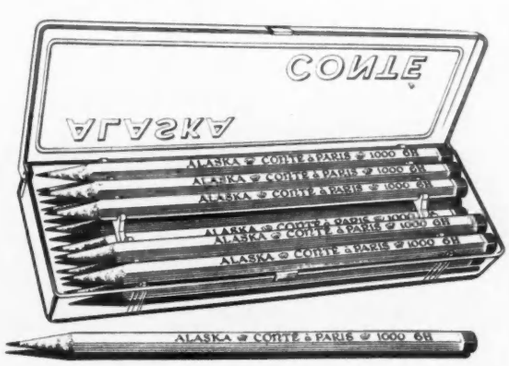

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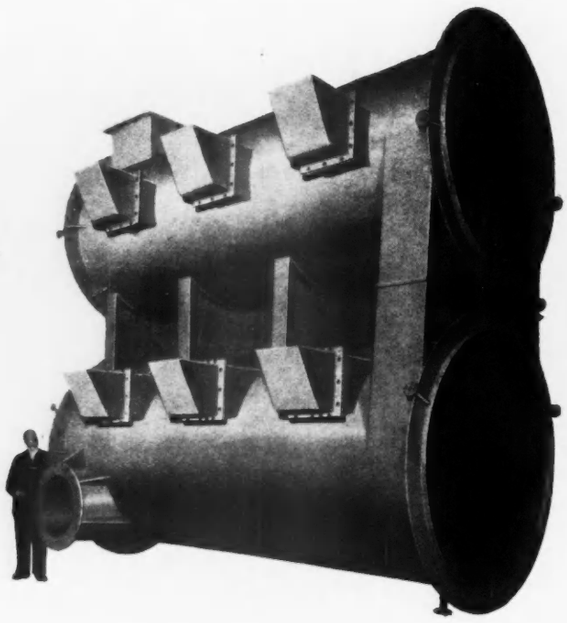

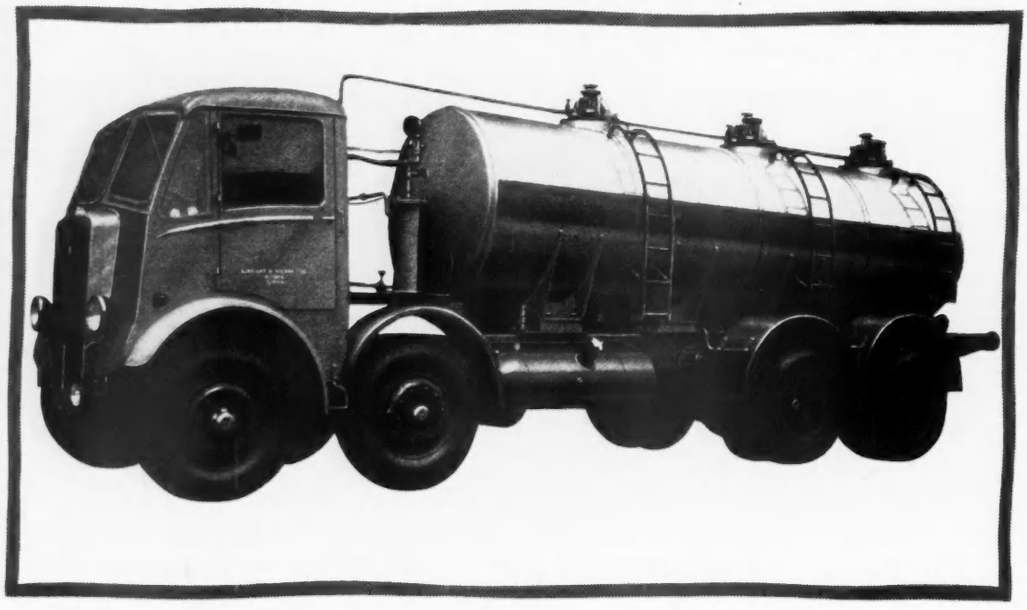

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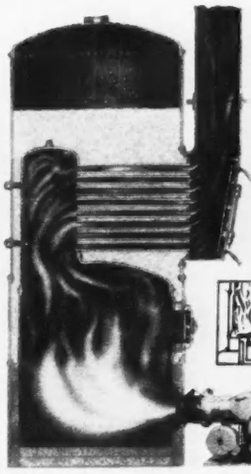

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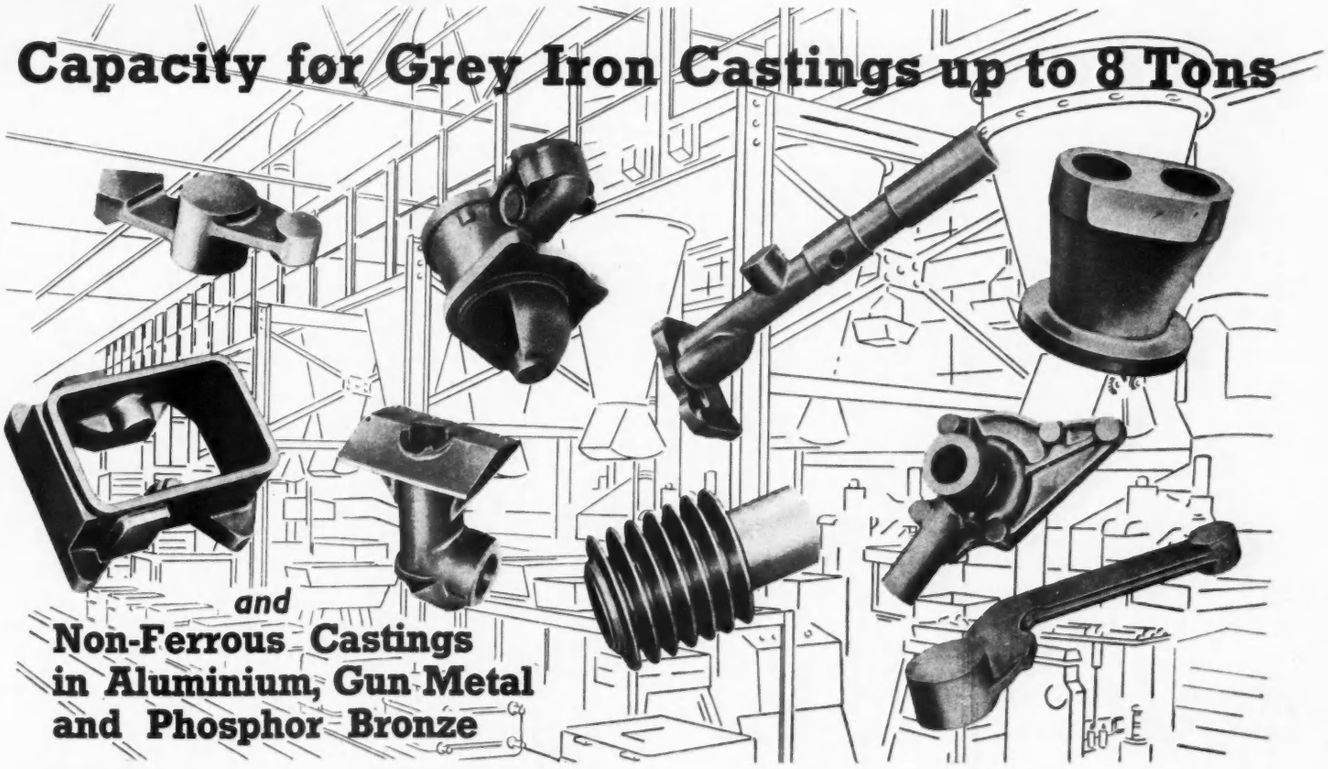

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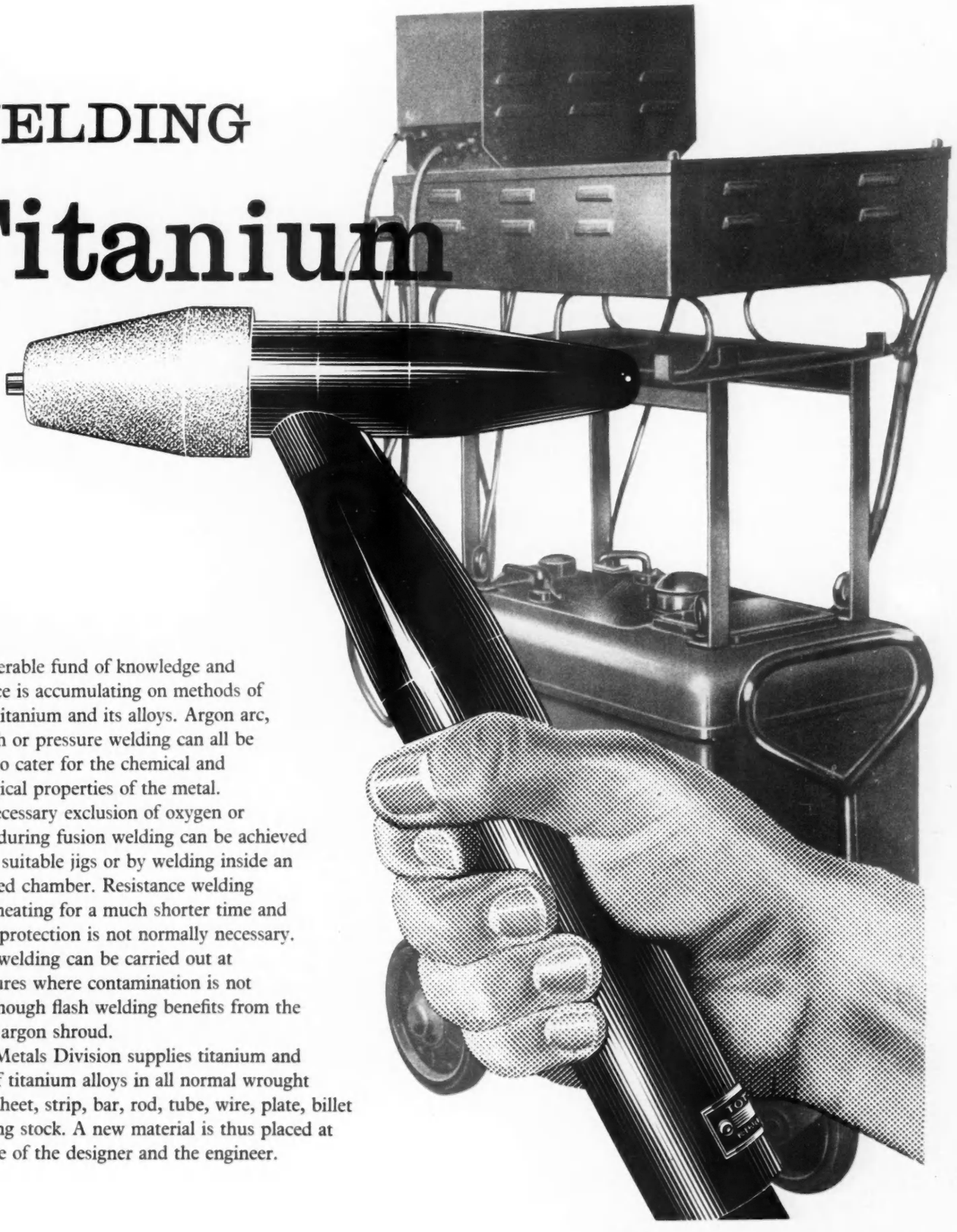

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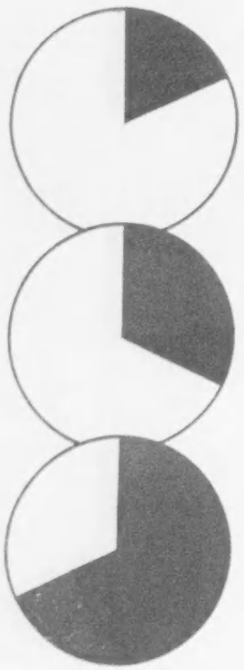

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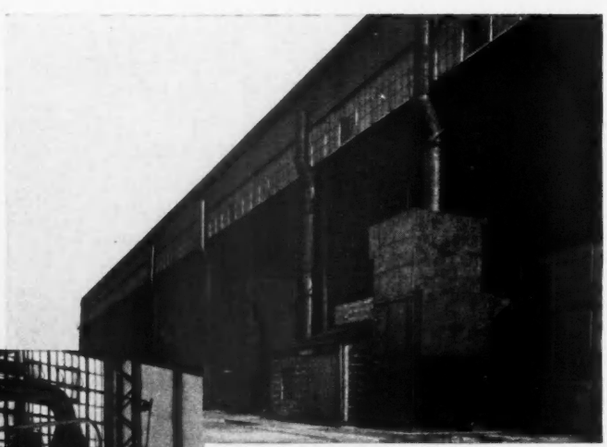

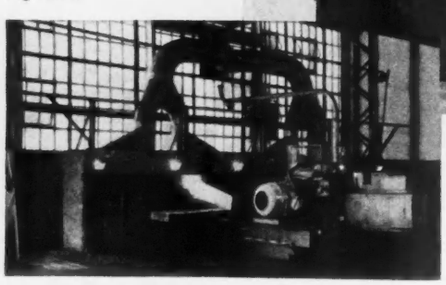

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Swing grinder dust exhaust plant with textile filters, equipped by Keith Blackman. Photographs by courtesy of Shepcote Lane Rolling Mills Ltd., Sheffield.

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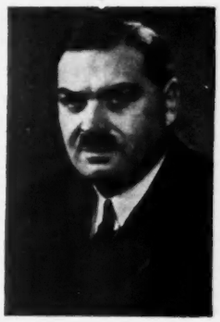

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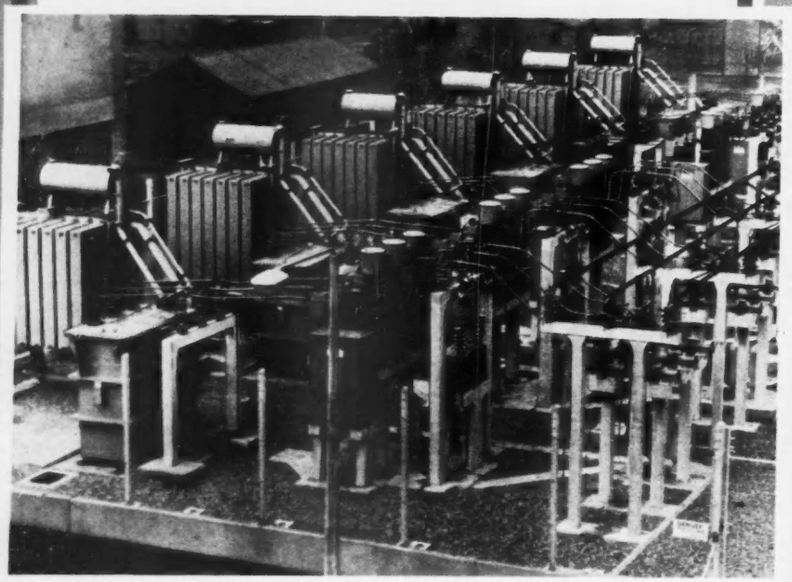

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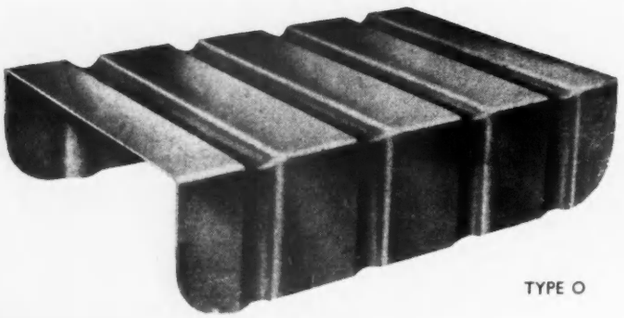

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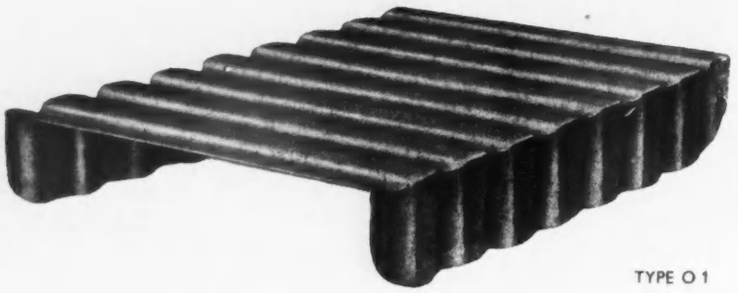

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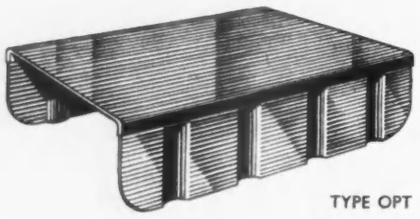

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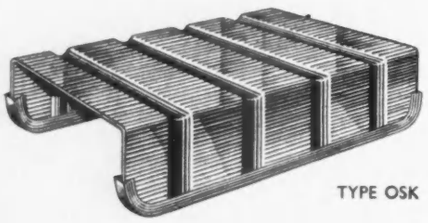
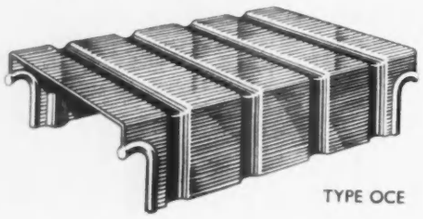


TYPE OSK



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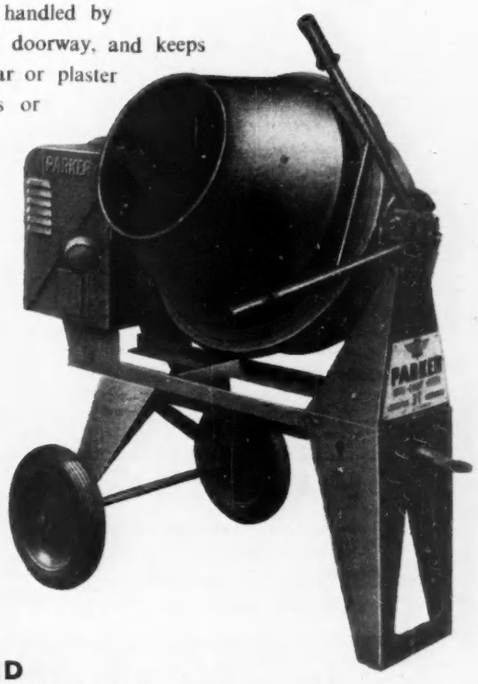

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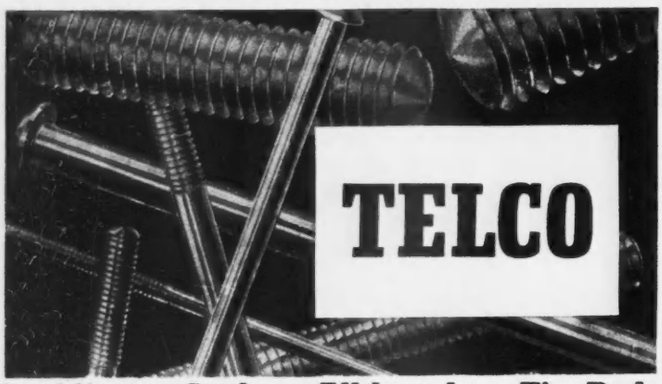

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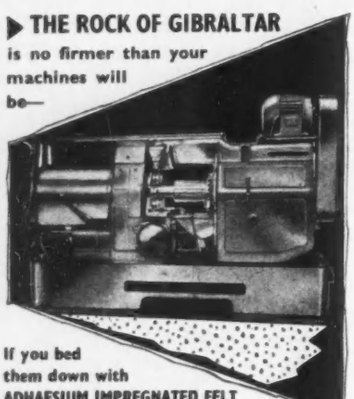

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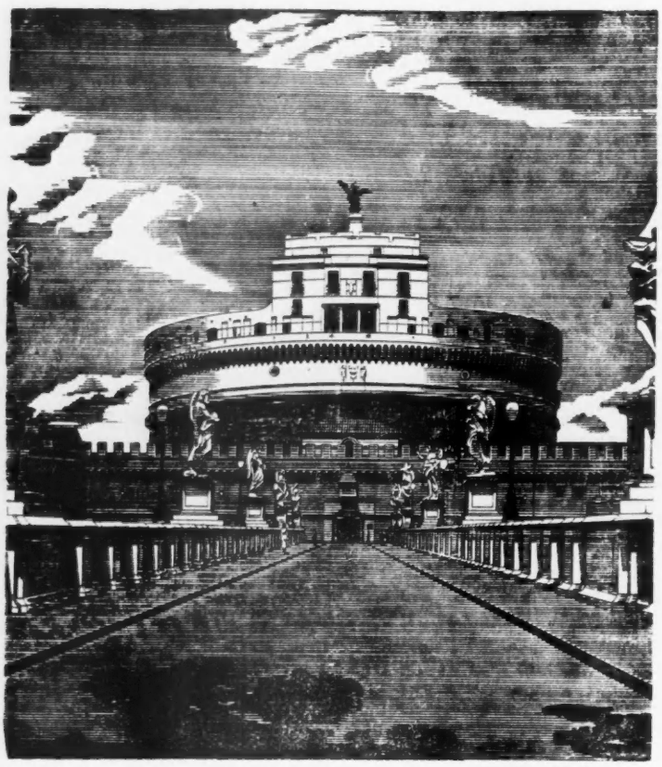

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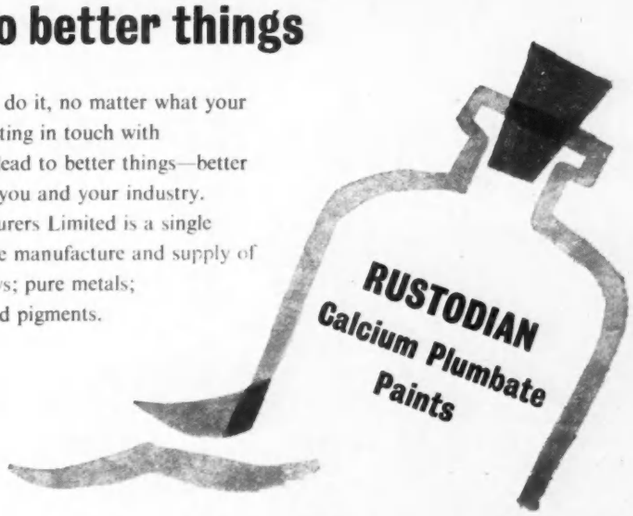

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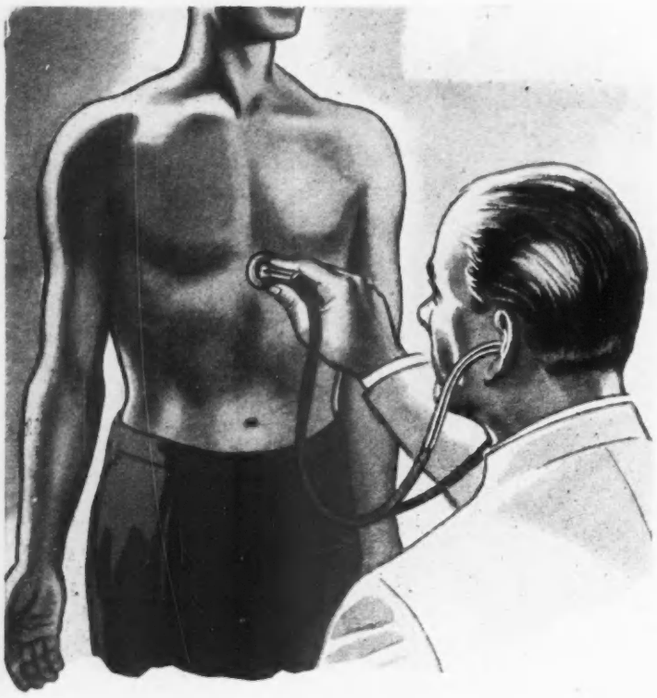

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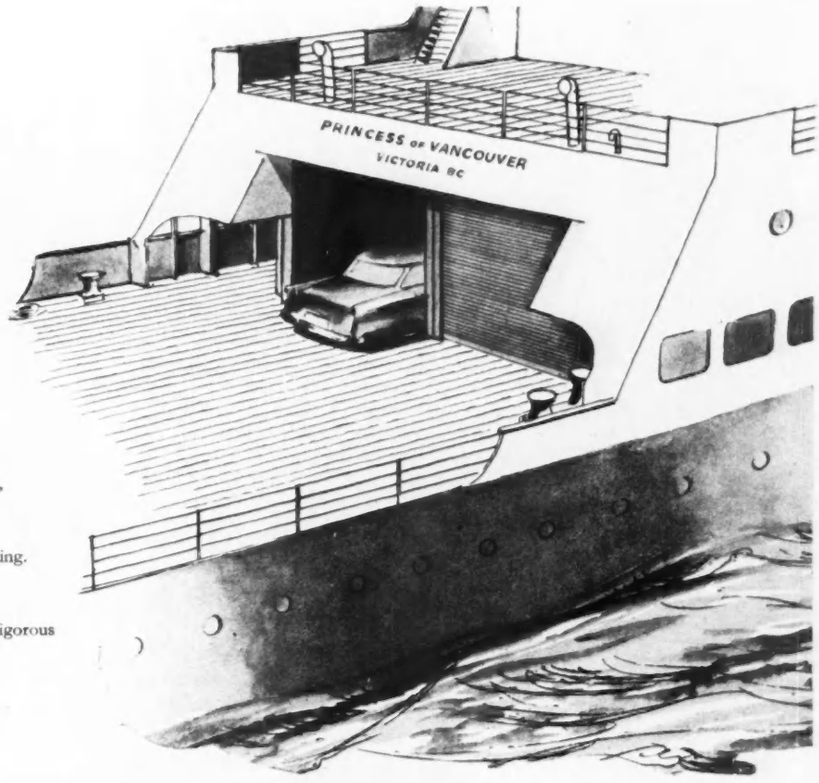

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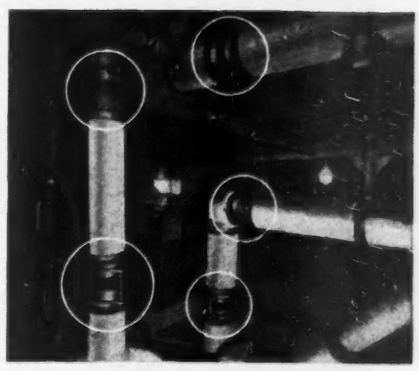

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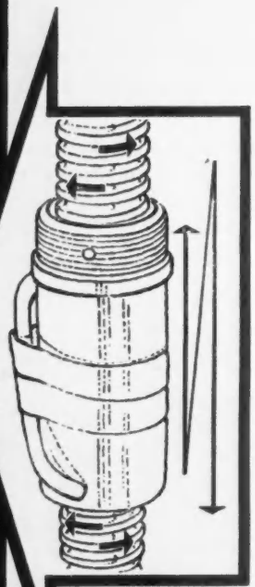

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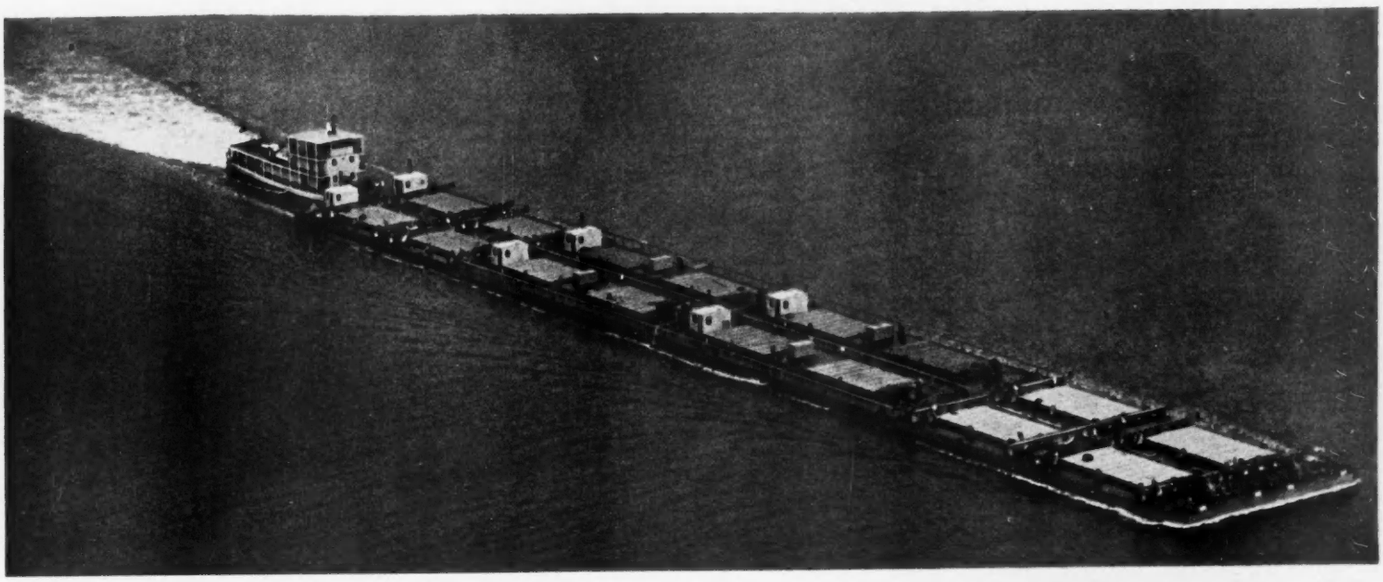

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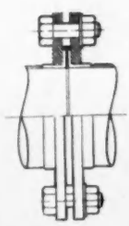
STAINLESS STEEL PIPING



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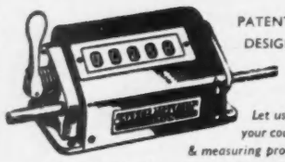

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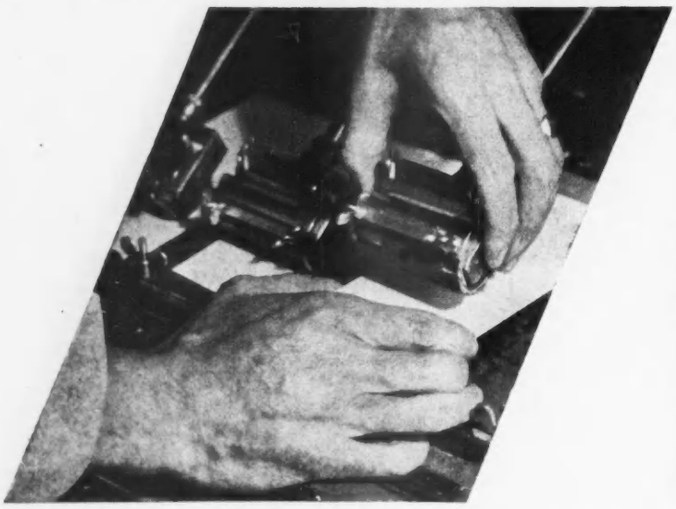

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VOLTMETERS
for use in laboratories, production lines and teaching establishments

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20 c/s to 300 Mc/s
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TC 146

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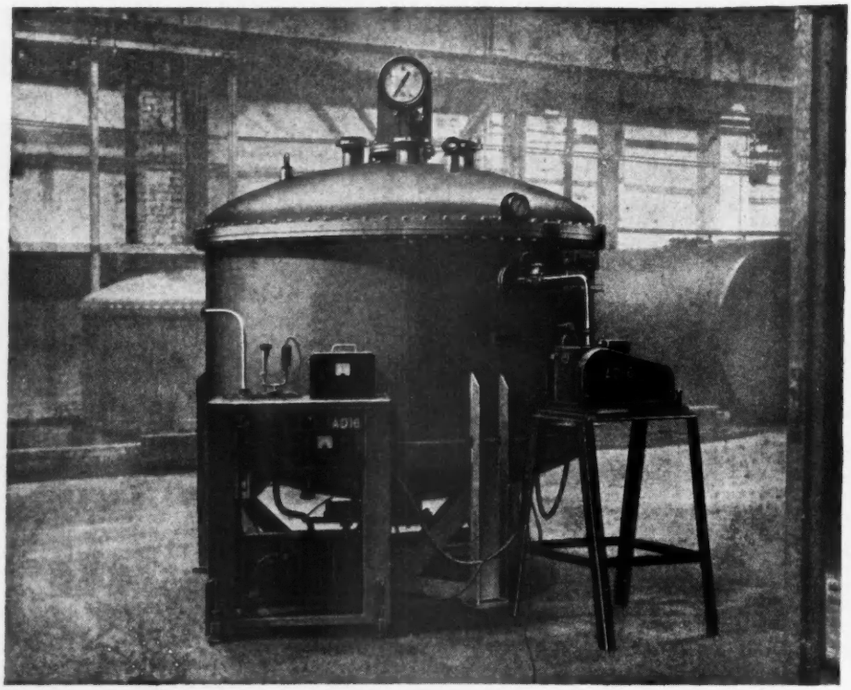
- *Illustrated: 2 tons capacity Liquid Oxygen Storage Tank, Inner vessel ¼" x ½" thick 18.8Ti Stainless Steel; jacket ⅜" x ½" thick mild steel. Jacket space filled with Expanded Perlite Inner vessel tested 100 p.s.i. Jacket tested 30 p.s.i. for ·01 mm. Hg. working vacuum. The illustration shows the vessels set up for vacuum tests for Air Products Limited for the Admiralty.*



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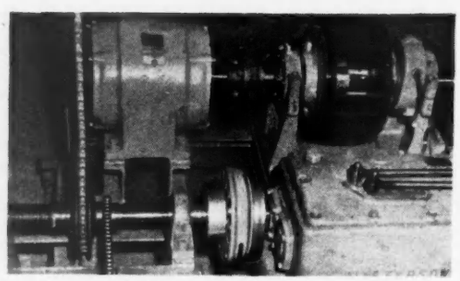
. . . for those demanding the BEST in machine control

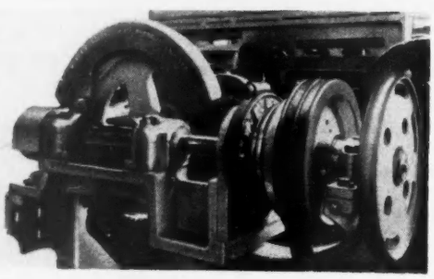
Warner Electric Brakes and Clutches are stepping up production, shrinking costs, reducing operator fatigue and saving time.

They give lightning-fast, yet smooth cushioned stops and starts; cycle, reverse and index at the touch of a button and are remarkably simple and foolproof in use. Operation is positive and easily controlled to produce the exact torque required.

Warner units occupy the minimum of shaft length, can be fitted to existing machines and enable new machines to be built smaller, faster and easier to operate. Automatic take-up for wear completely eliminates the need for adjustment.



Fully automatic re-winding machine showing a Warner 825 Clutch Coupling incorporated in the main drive.
The General Engineering Company (Radcliffe) Ltd., Radcliffe.



A Warner 1000 Clutch in the main drive of this heavy matting loom provides pre-positioned stopping and rapid starting with safety factors hitherto unknown for this class of loom.
Wilson & Longbottom Ltd. of Barnsley.

Our application Engineering Division is ready to advise at the design stage of new developments or on the conversion of existing machinery. Take action NOW.

Warner Electric Brakes & Clutches are manufactured in Great Britain under licence by:—

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For simplicity's sake fit WARNER ELECTRIC BRAKES & CLUTCHES

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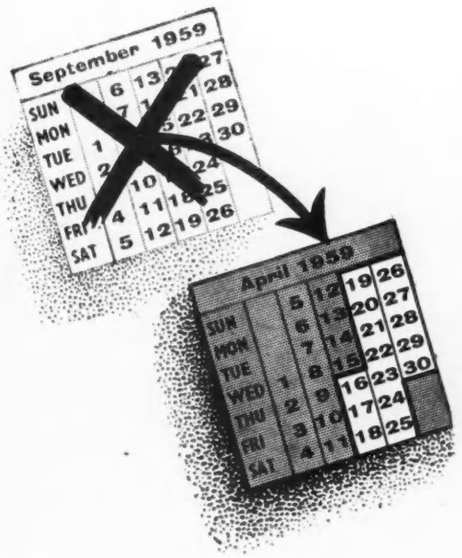

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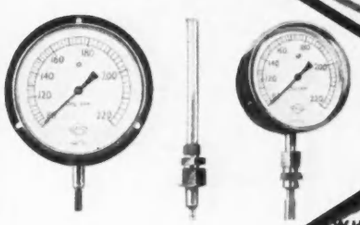

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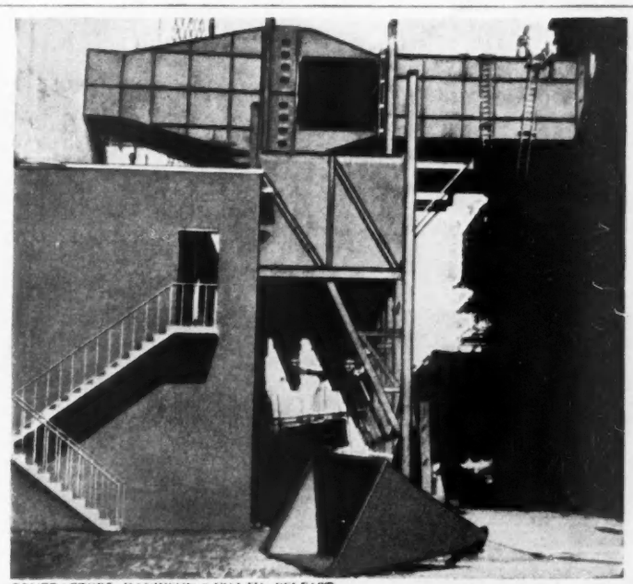

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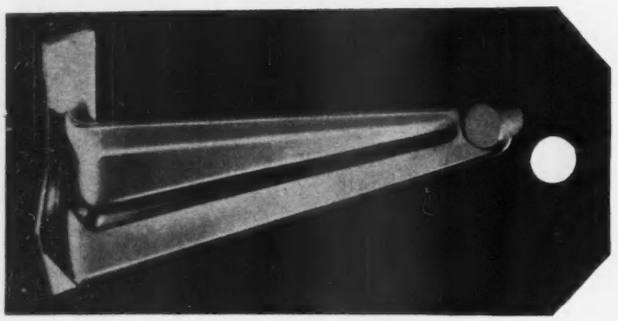

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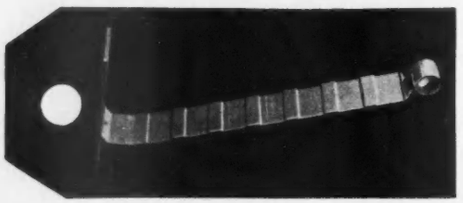

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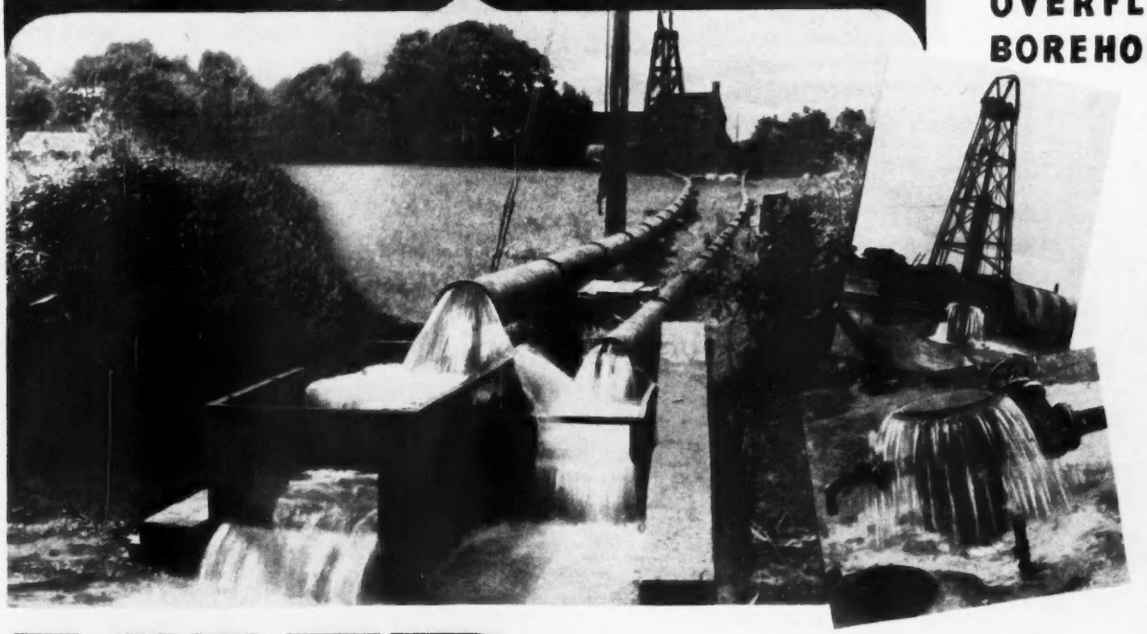

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Urgent advertisements may be telephoned to CENtral 6565

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THE TECHNICAL COLLEGE OF MONMOUTHSHIRE, CRUMLIN

Principal : Dr. T. V. STARKEY, F.Inst.P.

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T. M. MORGAN,
Director of Education.

County Hall,
Newport, Mon. E9873

UNIVERSITY OF DUBLIN

TRINITY COLLEGE

LECTURER IN MECHANICAL ENGINEERING

Applications are invited for appointment as LECTURER IN MECHANICAL ENGINEERING, to take up duty on September 21, 1959. The salary will be in the range £700 to £1100 per annum, with membership of a non-contributory superannuation and life assurance scheme.

Further particulars may be obtained from the Registrar, Trinity College, who will accept applications (three copies) until March 28, 1959. E9858

LOUGHBOROUGH COLLEGE OF TECHNOLOGY

SENIOR LECTURER IN MECHANICAL ENGINEERING

Applicants should possess good academic qualifications and have had experience in automatic control, preferably involving pneumatic or hydraulic systems.

Salary scale : £1417 10s. by £52 10s. to £1627 10s., with superannuation.

Application forms and further particulars from the Registrar, quoting ref. 1/C. E9865

PUBLIC APPOINTMENTS

NOTTINGHAMSHIRE EDUCATION COMMITTEE

MANSFIELD TECHNICAL COLLEGE

ASSISTANTS— ENGINEERING DEPARTMENT

Principal : R. F. BEATON, B.Sc.(Eng.), Wh.Sch.

Applications are invited for the following appointments in the Engineering Department :

(i) ASSISTANT GRADE "A" for teaching duties mainly in Pre-Senior courses and the lower stages of Craft Courses, the main subjects required being Mathematics, Engineering Drawing, Science and English. Candidates should be qualified to teach some of the above subjects and should have had suitable industrial and/or teaching experience.

(ii) ASSISTANTS GRADE "B." Several vacancies exist for suitably qualified candidates capable of teaching to one of the following levels : (a) Electrical Engineering Higher National Certificate, (b) Motor Vehicle Technicians, (c) Machine Shop Engineering Final, (d) Advanced Certificate for Colliery Mechanics and/or Electricians. Applicants should have relevant experience in the Engineering or Mining Industries and preferably some teaching experience.

The salary is in accordance with the Burnham Technical Scale. Grade "A" Assistants, £475 by £25 to £900 plus 5 per cent. Grade "B" Assistants £650 by £25 to £1025 plus 5 per cent. Additions may be made to the scales for certain qualifications and approved study-training. The starting position on the scales depends upon previous industrial and teaching experience.

A form of application may be obtained from the Divisional Education Officer, Education Office, Market Place, Mansfield, to whom it should be returned within 10 days of the appearance of this advertisement.

J. EDWARD MASON,
Director of Education.

County Hall,
Nottingham. E9906

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

HENDON TECHNICAL COLLEGE,
THE BURROUGHS,
HENDON, N.W.4

LECTURER IN MECHANICAL ENGINEERING

Required for 1st September, 1959 :
LECTURER IN MECHANICAL ENGINEERING. Candidates must be graduates with teaching and industrial or research experience. Ability to teach Applied Thermodynamics or Structures as applied to Aeronautical Engineering to Higher National Diploma standard.

Salary in accordance with Burnham (Technical) Report, 1956, i.e. £1200 by £30 to £1350, plus London allowance. This salary is now subject to 5 per cent increase.

Application forms and particulars (foolscap s.a.e.) from the Clerk to the Governing Body, Town Hall, Hendon, N.W.4. Closing date 27th February.

C. E. GURR, M.Sc., Ph.D.,
Secretary to the Education Committee.
E9888

UNIVERSITY OF BIRMINGHAM

DEPARTMENT OF INDUSTRIAL METALLURGY

LECTURESHIP

Applications are invited for a LECTURESHIP in the Department of Industrial Metallurgy to lecture to final year and post-graduate students. Good facilities are provided for research. Candidates should have a good degree and industrial or research experience ; and an interest in the application of science in the field of melting and casting would be an advantage. Salary within range £900–£1650 with F.S.S.U. and family allowance.

Applications (two copies), with the names of three referees, should be sent as soon as possible to the Deputy Registrar, The University, Birmingham, 15, from whom further particulars may be obtained. E9856

PUBLIC APPOINTMENTS

THE POLYTECHNIC,

309, REGENT STREET, W.1.

CIVIL AND MECHANICAL ENGINEERING DEPARTMENT

LECTURER IN CIVIL ENGINEERING

Applications are invited for the post of full-time LECTURER IN CIVIL ENGINEERING to teach Geology and Soil Mechanics to final Degree and Diploma students. The appointment will commence on 1st September, 1959. The salary scale commences at £1260 per annum, rising by annual increments of £31 10s. to £1417 10s., plus London allowance of £37 16s. or £50 8s. per annum. In special cases increments may be allowed in respect of previous professional experience. The post is subject to superannuation and some concession in this respect may be made for previous industrial employment.—Further particulars and a form of application, which should be returned not later than February 28th may be obtained from the undersigned.

J. E. RICHARDSON,
Director of Education.
E9908

ESSEX EDUCATION COMMITTEE

SOUTH-EAST ESSEX TECHNICAL COLLEGE,
LONGBRIDGE ROAD, DAGENHAM

HEAD OF THE MECHANICAL AND PRODUCTION ENGINEERING DEPARTMENT

Applications are invited for the post of HEAD OF THE MECHANICAL AND PRODUCTION ENGINEERING DEPARTMENT (Grade V). Candidates should have high academic qualifications together with teaching and industrial experience. The appointment will be effective from the earliest date possible.

Persons who applied in response to the earlier advertisements need not re-apply.

Salary : £1900 by £50 to £2050, plus London Allowance and the 5 per cent special addition.

Application forms and further details (stamped, addressed foolscap envelope) obtainable from the Chief Education Officer, County Offices, Chelmsford. Closing date, 7th March, 1959. E9905

JOINT IRON COUNCIL

TRAINING STAFF

ASSISTANT TO THE EDUCATION AND TRAINING OFFICER

Applications are invited for the post of ASSISTANT TO THE EDUCATION AND TRAINING OFFICER tenable in London.

The successful applicant should have industrial experience in the FOUNDRY INDUSTRY, and a suitable technical or academic qualification. Training and/or teaching experience desirable.

He will be required to assist in the development of training activities in the ironfounding industry, particularly for apprentices and technicians, and in arranging residential courses for supervisors.

The post requires energy, tact and perseverance and will entail visiting firms in the industry. The starting salary would be in the vicinity of £900, depending on qualifications and experience.

An application form and further particulars may be obtained from the Education and Training Officer, Joint Iron Council, 14, Pall Mall, London, S.W.1, and should be returned within 14 days of the appearance of this advertisement. E9894

ST. THOMAS' HOSPITAL,

LONDON, S.E.1

SENIOR ENGINEER

Experience in plant maintenance and supervision and maintenance of oil-fired W.T. Boilers, ancillary plant, thermal storage, heating, domestic hot water, kitchen equipment and mechanical ventilation, &c. Marine engineering qualification or equivalent Naval certificate desirable. Salary £770–£920 p.a. including London Weighting.—Further details upon application to the Personnel Officer. Closing date for applications with names of two referees, 28th February. E9892

PUBLIC APPOINTMENTS

ROYAL NAVAL SCIENTIFIC SERVICE

SENIOR SCIENTIFIC OFFICERS AND SCIENTIFIC OFFICERS

Royal Naval Scientific Service requires SENIOR SCIENTIFIC OFFICERS and SCIENTIFIC OFFICERS for establishments in London area, Baldock, Portsmouth, Portland, Poole and Rosyth. Main requirements are for PHYSICISTS, MECHANICAL ENGINEERS, ELECTRONIC ENGINEERS and MATHEMATICIANS in areas specified. The following particular vacancies also exist : Mathematician : for applied research of basic nature and stability of underwater vehicles ; knowledge of theoretical hydrodynamics and theory of control systems an advantage ; London area. Mechanical Engineer : with sound knowledge of basic principles of thermo and fluid dynamics, to carry out research programme in a particular field of applied hydrodynamics ; experience in modern methods of design and research on axial-flow compressors, turbines or pumps an advantage ; London area. Mechanical Engineers : for design and development of underwater devices ; Portland area. Physical Chemist : with specialised knowledge of rubber technology ; Poole area. Chemists : Physical and Inorganic ; Poole, Baldock and London areas. Candidates must normally be natural born British subjects of natural born British parents, with First or Second Class Honours Degrees or equivalent high professional attainments. S.S.O.s must have had three years' post-graduate experience and be not less than 26 years of age. Salaries (men) : S.S.O., £1190–£1410 ; S.O., £635–£1110 (London)—somewhat lower in provinces. Appointments are unestablished (with F.S.S.U. benefits), but opportunities may occur for those between ages of 21 and 32 to compete for established posts.—Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1 (quote A.500/8A). E9615

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

WARREN SPRING LABORATORY, STEVENAGE

MECHANICAL OR ELECTRICAL ENGINEERS

D.S.I.R.'s new Warren Spring Laboratory, Stevenage, requires MECHANICAL or ELECTRICAL ENGINEERS as Experimental Officers or Assistant Experimental Officers as follows :—(1) For design and development of experimental plant ; experience, including at least three years in drawing-office (ref. C47/9A). (2) For instrument development ; previous experience, particularly of electronic instruments desirable, but not essential for A.E.O. (ref. D31/9A). Qualifications : H.N.C. in Mechanical or Electrical Engineering for post (1). For post (2), G.C.E. "A" level in two Science or Mathematics subjects or equivalent. Over 22, Pass Degree, H.N.C. or equivalent generally expected. Men's salary ranges : E.O. (normally at least 26), £920–£1130 ; A.E.O., £370 (age 18) to £645 (26) to £800.—Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1 (quote appropriate reference). Closing date 6 March, 1959. E9875

KINGSTON GROUP HOSPITAL MANAGEMENT COMMITTEE

SENIOR ENGINEER

SENIOR ENGINEER, Kingston Hospital, Kingston-upon-Thames.

Applications are invited for above appointment under direction of Superintendent Engineer from suitably qualified persons. Salary : £740 by £25 (2) by £30 (3) to £880 per annum, plus London Weighting. Residence available at reasonable rental. Candidates must have served an apprenticeship and possess a sound knowledge of the operation of steam boiler plant, oil firing, and engineering services.

Details of age, qualifications and experience, together with names of two referees, to be sent within 14 days to the Group Secretary, Kingston Group Hospital Management Committee, 35, Coombe Road, Kingston-upon-Thames, Surrey. E9870

PUBLIC APPOINTMENTS

UNITED KINGDOM ATOMIC ENERGY AUTHORITY, INDUSTRIAL GROUP

CHAPELCROSS WORKS, ANNAN, DUMFRIESSHIRE

SENIOR ENGINEERS

SENIOR ENGINEERS are required by the United Kingdom Atomic Energy Authority, Industrial Group, in the Engineering Department of the nuclear power station now under construction at Chapelcross, which is responsible for the maintenance of nuclear reactors, steam turbines, associated electricity generating equipment, and all plant on the site. This includes normal equipment of conventional power stations as well as unusual and complicated mechanical, electrical and instrument equipment used in the operation and control of nuclear reactors.

The posts carry responsibility to the Works Engineer for the organisation and running of a section dealing with the inspection, commissioning and maintenance of (a) all mechanical plant, or (b) all electrical plant, or (c) all instrumentation in the works.

A recognised engineering apprenticeship (or comparable training for the instrumentation post), and Corporate Membership of an appropriate senior engineering institution are essential. Experience in the management of similar maintenance sections of large industrial organisations or power stations is desirable, but specialist experience in a particular field of engineering may be accepted.

Salary between £1790 and £2080, according to qualifications and experience.

Contributory superannuation. Staff housing scheme.

Send postcard for application form, quoting reference 2841/J1, to Works Secretary, Chapelcross Works, Annan, Dumfriesshire, Scotland.

Closing date : 23rd February, 1959. E9848

BISHOP'S STORTFORD URBAN DISTRICT COUNCIL

APPOINTMENT OF RESIDENT ENGINEER—SEWERAGE

(Re-Advertisement)

Applications are invited for the above appointment to supervise the construction of a new sewer and pumping station. The work will be executed by Contract and will be under the supervision of the Consulting Engineers, Messrs. J. D. and D. M. Watson, MM.I.C.E., 67, Tufton Street, London, S.W.1.

The salary offered is £1250 a year and subject to satisfactory service the appointment is expected to last for about 18 months. Applicants, who should have had extensive experience of sewer construction in built-up areas, should apply in writing to the Consulting Engineers at 67, Tufton Street, London, S.W.1, in the first instance, not later than Monday, 23rd February, 1959, giving full particulars of age, qualifications and experience and the name of at least two referees who would testify to character and ability.

G. NORMAN DRINKWATER,
Clerk of the Council.

The Council House,
Bishop's Stortford. E9909

THE BOARD OF GOVERNORS, THE HAMMERSMITH, WEST LONDON AND ST. MARK'S HOSPITALS

HAMMERSMITH POSTGRADUATE TEACHING HOSPITAL

SENIOR ENGINEER

Applications invited from suitably qualified candidates for the appointment of SENIOR ENGINEER at the Hammersmith Postgraduate Teaching Hospital (700 beds). Salary scale (now under review) £730–£870 per annum, plus London Allowance. A gratuity of up to 10 per cent. of salary will also be payable for hours worked in excess of normal 38-hour week. An additional payment will be made for supervisory duties for other authorities on the site. Modern three-bedroom house, with garage, available on special rental terms.—Full details of duties and conditions of service may be obtained from the Secretary, Board of Governors, Hammersmith Hospital, Du Cane Road, London, W.12. E9889

LANCASHIRE RIVER BOARD

ENGINEERING ASSISTANT

Applications are invited for the post of ENGINEERING ASSISTANT, A.P.T. I (£575–£725 per annum). Preference will be given to applicants who have taken part of the examinations of the Institution of Civil Engineers and who have had some experience in River Board and land drainage work. The successful applicant will be required to provide a car, for which an allowance will be paid up to a maximum of 1399 c.c. in accordance with the National Joint Council scales.

The post is superannuable and the successful applicant will be required to pass a medical examination. Applications, stating age, marital status, position regarding National Service, qualifications, technical training, experience, present and previous appointments, with salaries, together with the names and addresses of two persons to whom reference may be made, should be addressed to the Chief Engineer of the Board at 48, West Cliff, Preston, not later than Saturday, 28th February, 1959. E9869

PUBLIC APPOINTMENTS

ROYAL CORPS OF NAVAL CONSTRUCTORS

SCHOOLS ENTRY

A COMPETITION for ENTRY into the ROYAL CORPS OF NAVAL CONSTRUCTORS will be held in July, 1959.

2. Accepted candidates will be established as Probationers in the Royal Corps of Naval Constructors and will undergo a two-year course of training at the R.N. Engineering College, Manadon, and in H.M. Dockyard, Devonport, followed by a three-year course at the R.N. College, Greenwich.

3. Candidates must be aged between 18 years and 19 years 6 months, inclusive, at 1st September, 1959.

4. Candidates with the General Certificate of Education will be required to have passed at Advanced Level in at least Pure Mathematics, Applied Mathematics, Physics and to produce evidence of General Education at Ordinary Level.

5. Candidates with the Scottish Leaving Certificate will be required to have higher grade passes in Science, Mathematics, at least two additional mathematical subjects, and at least lower grade passes in English, and a language other than English.

6. Candidates from schools in Northern Ireland will be required to produce a certificate from the Ministry of Education in Northern Ireland showing a comparable standard to that above.

7. Applications will be considered from candidates who sit these examinations in 1959.

8. The work of the R.C.N.C. covers all aspects of design, construction and repair to H.M. Ships. Members undertake to serve wherever required at Admiralty headquarters, Outports in the United Kingdom and at Royal Dockyards at home and abroad. The present head of the R.C.N.C. is the Principal Technical Adviser to the Board of Admiralty.

9. The starting pay of a probationer at age 18 will be £527. A deduction of £75 is made when living in at the R.N. Engineering College, Manadon, or at the R.N College, Greenwich. The successful probationer can expect an appointment as Assistant Constructor at age 23 or 24, with a starting salary of not less than £880 and £910 respectively. Promotion to Constructor normally takes place at about age 30, with a salary which may be expected to be not less than £1465, rising in nine years to not less than £2100. Promotion to higher ranks is by selection.

10. Full particulars may be obtained from the Secretary of the Admiralty, Civil Establishments Branch II (88), Empire Hotel, Bath, quoting reference number 5914, to whom final application must be submitted by 15th June, 1959. E9808

SOUTH WARWICKSHIRE HOSPITAL GROUP (No. 14)

CENTRAL HOSPITAL, NR. WARWICK

ASSISTANT ENGINEER

Applications are invited for the post of ASSISTANT ENGINEER of this Mental Hospital (approximately 1450 beds), salary £585 per annum by £20 (1) by £25 (3) by £30 (1) to £710.

Person appointed will be responsible under the supervision of the Engineer-in-Charge for the operation and maintenance of the mechanical installations, including those in the laundry, kitchen and boiler house department, and also for deep well pumping and extensive heating and hot water installations and site generation. Applicants must be skilled in lathe and machine work and capable of controlling staff. O.N.C. in Mechanical Engineering or 2nd Class B.O.T. (M.O.T. or recognised equivalent). House available for which rent will be charged.

Applications with names of three referees to be sent to the Group Secretary, 50, Holly Walk, Leamington Spa. E9855

ADMIRALTY

LONDON, BATH, AND H.M. DOCKYARDS

ELECTRICAL ENGINEERS AND ASSISTANT ELECTRICAL ENGINEERS

Admiralty requires ELECTRICAL ENGINEERS and ASSISTANT ELECTRICAL ENGINEERS for unestablished appointments in London, Bath and H.M. Dockyards. Candidates must be British subjects, possess University Honours Degree or equivalent qualifications, with at least two years' practical training followed by practical experience in responsible post. Salaries depending on age and experience within ranges : Electrical Engineer, £1445 to £1975 ; Assistant Electrical Engineer, £865 (age 25) to £1345 (London rates, subject to reduction in provinces).—Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting D63/9A. E9874

BRITISH WATERWAYS

MECHANICAL INSPECTOR

British Waterways require a MECHANICAL INSPECTOR in their Divisional Engineer's Department based at Navigation Road, Northwich, Cheshire. Salary scale £711–£757 per annum, plus a commuted overtime allowance with Superannuation Scheme and certain railway privilege travel facilities.

Applicants should have considerable practical experience in operation and maintenance of Civil Engineering Plant and mechanical handling equipment. Workshop supervisory experience and working knowledge of electrical equipment also required. Knowledge of Factory Acts safety requirements essential.

Applications : Divisional Manager, British Waterways, Lime Street Chambers, Liverpool, 1, by February 27th. E9899

PUBLIC APPOINTMENTS

CITY OF BRADFORD WATER DEPARTMENT

APPOINTMENT OF SENIOR ENGINEERING ASSISTANTS

Applications are invited for two superannuable appointments : (a) ONE SENIOR ENGINEERING ASSISTANT, Grade A.P.T.V. (£1175–£1325) ; and (b) ONE SENIOR ENGINEERING ASSISTANT, Grade A.P.T.IV (£1025–£1175).

Candidates for these appointments must be Corporate Members of the Institution of Civil Engineers and should have a wide experience in water supply. They will be required for work in connection with the general maintenance of the water undertaking, and particularly in the design and construction of large aqueduct pipelines, bridges, culverts, rapid gravity filtration and sedimentation tanks extensions, reservoir construction works, distribution boosters, &c.

Applications, stating age, training, professional qualifications and experience, together with the names of two referees, must reach the undersigned by 7th March, 1959.

Canvassing will disqualify, and an applicant who is related to a member or a senior official of the Council must disclose the fact in his application.

W. H. LEATHEM,
Town Clerk.

Town Hall,
Bradford, 1. E9907

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

MECHANICAL ENGINEERING RESEARCH LABORATORY, EAST KILBRIDE, GLASGOW

EXPERIMENTAL OFFICER ENGINEER

D.S.I.R. Mechanical Engineering Research Laboratory, East Kilbride, Glasgow, requires an EXPERIMENTAL OFFICER ENGINEER for design and development work on very high fluid pressure equipment. Drawing-office and workshop training and experience of general mechanical engineering design essential. Knowledge of miniature precision mechanism or hydraulic pumps, valves, &c., or mechanical testing equipment an advantage. Will carry out detailed designs and have opportunity of testing and developing them in laboratory. Qualifications : G.C.E. (Advanced) in two science or mathematical subjects, or Scottish Leaving Certificate with three subjects, including science and mathematics in higher grade, but pass degree H.N.C. in Mechanical Engineering, or equivalent generally expected. Salary range : £954–£1166. Houses in East Kilbride for married staff.—Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting C76/9A. Closing date, 6th March, 1959. E9885

U.K.A.E.A. RESEARCH GROUP

DRAUGHTSMEN

(Ref. 1350/25)

Opportunities to enter the atomic energy field exist at the Atomic Energy Research Establishment, Harwell, and at A.E.A., Bracknell (Berks.), for draughtsmen (mechanical and electrical) with two years' D.O. experience, O.N.C. *and* an engineering apprenticeship. Further education, housing and superannuation schemes.

Salary up to £895, with good prospects.

PROJECT ENGINEER

(Ref. 1336/25)

A Professional Engineer is required at A.E.A., Bracknell, Berks., to be responsible for the control and technical guidance of a project engineering section giving a service to research teams at A.E.R.E., Harwell. All stages from design specifications to commissioning and liaison with scientists are involved. Experience in electro-mechanical/mechanical design essential.

Salary £1300-£1740.

Please send a POST CARD for details, quoting appropriate reference No., to :

The Group Recruitment Officer,
A.E.R.E., HARWELL, BERKSHIRE

E9847

MINISTRY OF WORKS

REQUIRES

ENGINEERING DRAUGHTSMEN IN THE FOLLOWING CATEGORIES

HEATING AND VENTILATING
Design of all types of installations, including air conditioning.

ELECTRICAL
Design of lighting, power and special type installation, and site distribution schemes.

STRUCTURAL
Design and detailing of reinforced concrete or structural steelwork.
For employment in LONDON and PROVINCES on major site developments and all classes of PUBLIC and INDUSTRIAL BUILDING.

GENERAL CONDITIONS

Salary range £550 (age 21) to £870 p.a. in London (slightly less elsewhere). Starting point according to age, qualifications and experience ; 5-day week ; 3½ weeks' annual leave initially, and concessions for higher technical training in approved cases. Prospects of promotion to posts with salaries of £1015 p.a. and above. Opportunities for permanent posts leading to pensions, non-contributory.

QUALIFICATIONS
Technical education to O.N.C. or equivalent standard.

APPLICATIONS
State age, experience, training and qualifications, to : The Chief Engineer, Ministry of Works Room 435, Abell House, John Islip Street, LONDON, S.W.1.
Interviews at Regional Offices when possible.

E9500

Classified Advts. continued on page 110

PUBLIC APPOINTMENTS

CENTRAL ELECTRICITY GENERATING BOARD

RESEARCH & DEVELOPMENT DEPARTMENT

ASSISTANT ENGINEERS and PHYSICISTS Ref. ENR/46

required at the Research Laboratories, Leatherhead, Surrey, to work on problems associated with Electrostatic Precipitators and with Heat Exchangers for nuclear power stations. In both cases much of the work will be of a fundamental nature, carried out on pilot-scale plant, and importance will be attached to a sound basic knowledge.

Salaries will be on scales within the ranges £1195–£1775 p.a., or £570–£1300 p.a., according to duties and responsibilities.

Candidates for the higher grade vacancies should have an Honours Degree with previous research experience ; for the other vacancies a Pass Degree or H.N.C. would be acceptable.

WELDING METALLURGIST Ref. ENR/36

required in the Chemistry and Metallurgy Section of the Research Laboratories, Leatherhead, Surrey.

The successful candidate will be responsible for the investigation of welding problems associated with the construction and operation of conventional and nuclear power stations.

Applicants should have an Honours Degree or equivalent, and must be fully conversant with welding theory and practice ; and preferably have had experience of the problems associated with welding austenitic steels.

Salary on a scale within the range £1195–£1775 p.a., according to duties and responsibilities.

MECHANICAL ENGINEERS Ref. ENR/35

required in the Mechanical and Civil Engineering Section of the Research Laboratories, Leatherhead, Surrey.

Engineers with a good theoretical background are required, but it is also important that they should be able to undertake practical experimental work into a variety of problems involved in the generation of electricity in both conventional and nuclear power stations.

The Section is at present engaged on problems of vibration and fatigue of heat exchanger tubing, and the development of a rig for the investigation of steam turbine blade vibration and fatigue under rotating conditions at operating temperature.

Candidates should have an Honours Degree in Engineering or equivalent qualifications, and preferably some research or development experience.

Salaries on a scale within the range £570–£1300 p.a., according to duties and responsibilities.

Application forms obtainable from I. G. Ellis, Personnel Officer, 24/30, Holborn, London, E.C.1, should be completed and returned by 2nd March. Please mark envelopes "Confidential," quoting relevant reference number.

E9897

TENDERS

HALSTEAD RURAL DISTRICT COUNCIL

HEDINGHAMS AND GREAT YELDHAM DRAINAGE

CONTRACT NO. 9

TO MANUFACTURERS OF CENTRIFUGAL PUMPING PLANT

TENDERS are invited for the MANUFACTURE, SUPPLY and ERECTION of 7 SETS of VERTICAL UNCHOKEABLE SEWAGE PUMPS and ANCILLARY EQUIPMENT. The plant will be contained in two pumping stations. Two pumps shall be capable of a duty of 150 gallons per minute against a total head of 34ft.; two pumps for a duty of 250 gallons per minute against 30ft. total head ; two pumps for a duty of 375 gallons per minute against 30ft. total head ; and one pump for a duty of 325 gallons per minute against 37ft. total head, all in accordance with the specification and drawings prepared by the Engineers, Messrs. John Taylor and Sons, Artillery House, Artillery Row, Victoria Street, Westminster, S.W.1.

Copies of the specification and drawings may be obtained from the offices of the Engineers upon payment of £5 (cheque only, drawn favour of the in above Council), which will be returned on receipt of a bona-fide Tender not subsequently withdrawn. The contract documents may be inspected at the offices of the Engineers or the Council Offices.

Tenders, in plain, sealed envelopes, endorsed "Pumping Plant—Contract No. 9," are to be delivered to the undersigned on or before noon on the 11th March, 1959.

(Signed) H. E. P. STOKES,
Clerk of the Council.

Rural Council Offices,
Mount Hill,
Halstead,
Essex.

E9850

INDIA STORE DEPARTMENT

The Director General, India Store Department, Government Building, Bromyard Avenue, Acton, London, W.3, invites TENDERS for the SUPPLY of:

Pusher Type PAINT DRYING CABIN with Monorail Plant for drying structural steel and sheet metal parts painted with red-oxide primer and synthetic resin paints.

Please quote reference No. 18109/GNK/HAL.

The Tender forms, with schedules and specifications which are returnable on Thursday, 12th March, 1959, may be obtained from the above office (C.D.N. Branch), on payment of a fee (which is not refundable) of ten shillings for each Tender. Applications for Tenders should clearly state the reference numbers of the Tenders required. E9872

TENDERS

CITY OF NOTTINGHAM

WATER DEPARTMENT

TRIAL BOREHOLE

PROPOSED OMPTON PUMPING STATION

TENDERS are invited from experienced contractors for the SINKING and TEST PUMPING of a TRIAL BOREHOLE and other Appurtenant Work at a site in the Parishes of Ompton and Wellow, Southwell Rural District, Notts.

General conditions of contract, specification and form of Tender may be obtained from Mr. B. W. Davies, Engineer and General Manager, Water Department, Castle Boulevard, Nottingham, on payment of £1 1s. 0d., which will be returned in full on receipt of a bona-fide Tender, not afterwards withdrawn, and the return of all documents.

Tenders, enclosed in an envelope endorsed "Tender for Trial Borehole, Ompton Pumping Station," to be delivered to me at the Guildhall, Nottingham, not later than noon on Monday, the 16th March, 1959.

T. J. OWEN,
Town Clerk.

The Guildhall,
Nottingham.

E9884

KINGDOM OF THAILAND

ROYAL IRRIGATION DEPARTMENT BANGKOK, THAILAND

The Royal Irrigation Department of the Kingdom of Thailand requests sealed written bids for FURNISHING and DELIVERING c.i.f. Bangkok Wharf, for the Yanhee Multipurpose Project, Kingdom of Thailand, in accordance with the Contract Documents, including Invitation for Bids—No. YS–3–1—the following equipment :—

TWO (2) Vertical-Shaft, Alternating Current GENERATORS, 73,684kVA, 95 per cent power factor, 150 r.p.m., 13,800-volt, 3-phase, 50-cycle, including accessories and spare parts.

Bids will be opened at 10.00 a.m., 28th April, 1959. Copies of Contract Documents, including Invitation for Bids—No. YS–3–1—may be obtained by qualified bidders on written request on bidder's letterhead, addressed to Royal Irrigation Department, Attention: Thai Liaison Engineer, c/o Engineering Consultants, Inc., 1940, West Mississippi Avenue, Denver, 23, Colorado, U.S.A. Each request must be accompanied by a cheque or money order, payable to the Royal Irrigation Department, in the amount of U.S. $10.00 for each copy of the contract documents requested.

M. L. XUJATI KAMBHU,
Director General,
Royal Irrigation Department.

E9901

TENDERS

DEPARTMENT OF PUBLIC WORKS, NEW SOUTH WALES, AUSTRALIA

CLARENCE HARBOUR WORKS,
ASHBY DOCK,
CONTRACT No. 22–58/59 H AND R

TENDERS are invited for the SUPPLY, DELIVERY, ERECTION and TESTING of one "Scotch Derrick" Hand, alternatively Power, Operated CRANE, capable of lifting 10 tons at a maximum radius of 50ft. and 12 tons at 42ft. radius.

Specification No. 22–58/59 H & R may be obtained on application to the Agent-General for New South Wales, 56/57, Strand, London, W.C.2.

Tenders must be delivered to the Tender Board of the Department of Public Works, N.S.W., Bridge and Phillip Streets, Sydney, New South Wales, Australia, not later than 2 p.m. on Monday, 30th March, 1959. E9890

DEPARTMENT OF PUBLIC WORKS, NEW SOUTH WALES, AUSTRALIA

CLARENCE HARBOUR WORKS,
ASHBY DOCK,
CONTRACT No. 40–58/59 H & R

TENDERS are invited for the DESIGN, SUPPLY and DELIVERY of ONE PAIR of DOCK GATES constructed of non-corrosive metal, alternatively mild steel, which are required to replace existing timber gates at Ashby Dock.

Specification No. 40–58/59 H & R may be obtained on application to the Agent-General for New South Wales, 56/57, Strand, London, W.C.2.

Tenders must be delivered to the Tender Board of the Department of Public Works, N.S.W., Bridge and Phillip Streets, Sydney, New South Wales, Australia, not later than 2 p.m. on Monday, 27th April, 1959.

E9891

EDUCATIONAL

UNIVERSITY OF MANCHESTER

A FULL-TIME COURSE OF POST-GRADUATE LECTURES on the ADVANCED THEORY OF STRUCTURES will be held in the University of Manchester between July 6th and 18th, 1959.

The Lectures are intended for Engineers, Lecturers and Research workers who wish to study and discuss recent work in the subject. The lecturers will be Professor J. A. L. Matheson and Dr. J. E. Gibson, of the University of Manchester ; Dr. N. W. Murray, of the University of Sheffield, and Dr. R. K. Linsley, of Cambridge. The topics to be covered include the general theory of hyperstatic structures ; stability of frameworks, matrix analysis of structures ; the use of computing machines for frameworks and shells.

The fee for the lecture course is £15.

Accommodation for those requiring it will be arranged at one of the University's Halls of Residence.

Further particulars may be obtained from the Registrar, The University, Manchester, 13. E9849 E

A.M.I.MECH.E., B.Sc., City and Guilds, &c. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent successes. 148-page prospectus free on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London, W.8. E114 E

AUTOMATION.—AUTHORITATIVE COURSES are now available in Digital and Analogue Computer Technology, Applied Electronics, Data Processing and Instrumentation up to professional level by home study. Individual enrolment or industrial group scheme enrolments accepted. Syllabuses and prospectus sent on request.—Write (Dept. S.E.8), E.M.I. Institute School of Electronics, College House, Kensington, London, W.8. E145 E

SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES, NOT ORIGINALS, OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

AN EXPANDING WEST END BUSINESS WANTS SENIOR ENGINEER with practical knowledge of Tape Recording Amplifiers, to help develop new project. Apply.—BOX No. E2292, "The Engineer." A

ASSISTANT TO MANAGING DIRECTOR required by small, but important, steel firm. First-class technical and business qualifications essential.—Write, in strictest confidence, to Managing Director, reference P.A., BOX No. E9853, "The Engineer." A

COLGATE-PALMOLIVE, LIMITED,
MANCHESTER,
invite applications from
DESIGNER-DRAUGHTSMEN

with experience of chemical plant layout and design. Knowledge of service pipework arrangements an advantage and H.N.C. called for. Salary and conditions of employment are good in a modern factory with excellent accommodation and amenities.—Applications, giving details of age, salary expected, training, qualifications and experience, should be sent to Factory Personnel Manager, 371, Ordsall Lane, Salford, 5.

E9898 A

BRITISH COMPANY, WORLD - WIDE REPUTE, producing Marine, Industrial, Automotive diesel engines, has inside vacancy London sales office for thoroughly experienced COMMERCIAL ASSISTANT, preferably 35/40. Essential qualifications sound practical knowledge general office routine and export trade procedures, ability handle inquiries, including preparation specifications, quotations and all correspondence relating thereto. Salary commensurate. Contributory superannuation scheme exists. Confidential applications, stating age, full details and positions held.—BOX No. E9894, "The Engineer." A

SITUATIONS VACANT

"CONTROL SYSTEMS AND INSTALLATION"

James Howden and Co., Ltd., invite applications from ENGINEERS with experience of industrial control systems, instrumentation, &c., for a new appointment in their Technical Engineering Dept.; some experience of vibrations and noise control is desirable. Duties cover investigation, design and development work in connection with Howden installations and auxiliaries.—Applicants, who should be of Graduate standard and of about 30 years of age, should apply in the first instance to PERSONNEL MANAGER, JAMES HOWDEN AND CO., LTD., 195, SCOTLAND STREET, GLASGOW, C.5.

E2298 A

DRAUGHTSMAN required for interesting work on plant design, layout and services in expanding medium-sized chemical works. Pleasant office, staff bonus, contributory superannuation scheme and re-housing assistance.—Write (in confidence) to : Engineering Dept. Manager, JOHN & E. STURGE, LTD., Denison Road, Selby, Yorkshire. E9861 A

DRAUGHTSMEN, SENIOR DESIGNERS, with a thorough knowledge of mechanical handling, urgently required near Liverpool. Generous salaries to experienced men. Write in confidence, stating qualifications and experience.—BOX No. F9900, "The Engineer." A

ENGINEERING DESIGNER DRAUGHTSMAN REQUIRED

Candidates should have H.N.C. in Mechanical Engineering, or some recognised equivalent qualification, together with an engineering apprenticeship.

The post involves work of a varied and interesting nature on medium to heavy industrial process plant.

Experience required is that of general mechanical design, including plant installation.

The appointment is a permanent one and staff conditions are good.

Advantages include :
A 5-day week of 40 hours.
Three weeks' paid holiday per annum.
Additional holiday for long service.
Payment for overtime.
Staff pension scheme.
Excellent canteen and welfare facilities.
Assistance with housing.
Family separation allowance.
Removal expenses paid.

Those interested should apply to :
SP.A. Department,
Michelin Tyre Co., Ltd.,
Stoke-on-Trent, Staffs,
quoting reference No. B/324/TE.

E9773 A

ENGINEERING MANAGER required now for control of production sequences, estimating, fabrication procedure and drawing-office in works undertaking unusual fully welded large structures. A background of bridge, pressure vessels or shipbuilding fabrication is essential. Suitable qualifications are desirable, but not necessary. Age 30/45, minimum commencing salary £1600 per annum. Southern England, house available.—Write E726, L.P.E., Romano House, 399/401, Strand, London, W.C.2. E9867 A

ENGINEERING SALES. — A TECHNICAL REPRESENTATIVE is required by leading manufacturers of power station and industrial water-tube boilers and associated steam engineering equipment. Age range : 35–50 years. Essential qualifications are an intimate knowledge of subject plus good technical qualifications and experience at the level indicated, also ability to present a convincing case for a first-class product.—Applications, with full details of previous experience and an indication of the salary required, should be addressed.—BOX No. E9876, "The Engineer." A

EXPERIENCED DESIGN ENGINEER.—A progressive engineering organisation in the Midlands offers an excellent opportunity for a Mechanical Design Engineer to build up and lead a team on the design and development of packaging machinery. Applicants must have had practical experience in the design of packaging machinery. This is an important appointment and a commensurate salary will be offered. The company has a staff pension scheme.—Apply, giving full particulars of experience and qualifications, to C.E. Dept., BOX No. E2297, "The Engineer." A

EXPERIENCED DETAILING DRAUGHTSMAN required for Hull area. Starting salary range £700–£800 according to experience. Pension Scheme. Full details.—BOX No. E9862, "The Engineer." A

MOUNT ISA MINES, LIMITED

Experienced qualified MECHANICAL ENGINEERS required for large mine in Queensland, Australia. Commencing salary varies according to qualifications and experience up to £A2000 per annum, plus bonus of approximately £A200 per annum. Housing available, passage and travelling expenses paid. — Apply, with particulars, to MOUNT ISA MINES, LIMITED, ADELAIDE HOUSE, KING WILLIAM STREET, LONDON, E.C.4.

E9851 A

MAINTENANCE ENGINEER REQUIRED, to be responsible to the Chief Engineer for the supervision and organisation of machinery and building maintenance.—Apply, with full details of experience, copies of references, present salary, to the Managing Director, The Croft Granite, Brick and Concrete Co., Ltd., Croft, Nr. Leicester. E9886 A

SITUATIONS VACANT

MECHANICAL AND ELECTRICAL DRAUGHTSMEN

required by

W. H. ALLEN, SONS AND CO., LTD., BEDFORD

Applications are invited from both Design Draughtsmen and Detail Draughtsmen, preferably experienced in one or more of the following :

(a) A.C. and D.C. generators, motors and control gear.
(b) Diesel engines.
(c) Centrifugal, axial and mixed-flow pumps.

These are permanent appointments upon interesting work with good prospects. Generous pension scheme ; assistance towards removal expenses.

Apply, in writing, giving full details of experience, to the Personnel Manager.

E9803 A

PLANT MANAGER required to operate from new Depot at Reigate and to maintain extensive fleet of Contractors' Plant.—Write, giving full details of experience and salary required to Twentieth Century Equipment Company (London), Ltd., 244, Harrow Road, Paddington, W.2. E9857 A

PROJECT ENGINEER

An internationally known engineering Group of Companies in the Chemical and Oil Refinery contracting industry require a first class man for liaison with clients and co-ordination of specialist design groups on large-scale projects.

Applicants aged up to 40, should already hold a similar position. Essential qualifications are A.M.I.Chem.E. or A.M.I.Mech.E.

Commencing salary in the region of £1750 p.a. Our staff have been advised of this vacancy. Please write in confidence.—BOX No. E9863, "The Engineer."

A

QUALIFIED ENGINEER, A.M.I.Mech.E. or B.Sc., age 28–35. Salary according to experience, but not less than £1200 per annum. Superannuation after approved period. Application in writing, with résumé of experience, to JOHN YOUNG AND CO. (SHEFFIELD), LTD., Clement Street, Sheffield, marked for the attention of Mr. R. Burns.—All applications will be treated in strict confidence.

E9831 A

RESEARCH DIRECTOR OF AN INDUSTRIAL ASSOCIATION REQUIRES AN ASSISTANT with metallurgical qualifications and administrative experience preferably in iron and steel manufacture or foundry industry. Suitable applicants retiring or already retired from responsible active industrial posts would be considered. Birmingham area. State salary required.—BOX No. E2296, "The Engineer." A

SALES ENGINEER REQUIRED FOR NIGERIA

This is a post for a man with a sound engineering training and practical experience, preferably mechanical, who has the ability to sell. Remuneration between £1450 and £1700, depending on age and experience. Family allowances and pension scheme, free passages for employee and family, and free furnished accommodation in Africa. Leave every 20 months. Please write, giving full details.—BOX No. E9902, "The Engineer." A

SENIOR DRAUGHTSMEN, experience mechanical handling essential. Good rates of pay and bonus scheme.—Apply in writing to : Paterson Hughes Engineering Company, Ltd., Bedford House, Bedford Street, W.C.2. E2300 A

TECHNICAL ASSISTANTS (PATENTS).—The Dunlop Patent Department, a central organisation of the company located in their Research Centre at Birmingham, desire to appoint one or two Chemists and an Engineer, all with adequate patent experience, to responsible positions, where they will handle British and foreign applications with minimum supervision. Also an Engineer without patent experience to be trained as a Patent Agent. Applications are invited, preferably from Graduates, giving, in confidence, brief details and salary expected. Usual five-day week, pension scheme, good prospects and working conditions.—Please reply, quoting reference J.M.162, to Personnel Manager, DUNLOP RESEARCH CENTRE, Erdington, Birmingham, 24. E9792 A

TOOL DESIGN/METHODS ENGINEER to study and revise methods in use in a modern instrument factory and design necessary special purpose tools and machines, &c. The successful applicant will be under 35 years of age ; will have had tool design and method investigation experience in the light engineering industry ; have a knowledge of materials, mechanics and mathematics to O.N.C. standard, and will earn a salary suitable to his capabilities.—De Grave Short and Co., Ltd., Cray Valley Works, Orpington, Kent. Mark envelope M.D.'s.SEC/W.M. E2293 A

TRANSLATORS required. Must be British by birth and education, able to write fluent English, accustomed to handling highly technical German texts ; journalistic experience desirable.—State subjects handled, typing ability and minimum fees.—Brunton Translations, Charlotten-Str. 47, Dusseldorf, Germany. E2290 A

CHIEF ENGINEER

Peter Dixon and Son, Limited, require a Chief Engineer for their paper mill at Grimsby, Lincolnshire.

Applicants should have a Degree in Mechanical Engineering and Corporate Membership of the Institution of Mechanical Engineers.

The preferred age range is 40–50.

The successful candidate would be responsible for the Design, Development, Construction and Maintenance of all the plant, which includes six paper machines with ancillary plant, workshops, boiler plant and a back-pressure power plant producing 120,000 lb. of process steam per hour.

Considerable organising ability is a necessary qualification.

The Company operates an excellent pension scheme and will pay a good salary to the right man. A modern house is available and removal expenses are paid.

Detailed applications should be made in confidence to The Directors, Peter Dixon and Son, Limited, West Marsh Paper Mills, Grimsby, Lincolnshire.

E9866 A

ESTIMATOR

PLATEWORK FABRICATIONS MECHANICAL HANDLING PLANT.

Estimator wanted with good experience of platework fabrications and mechanical handling plant, including machine shop and fittings work. Excellent opening with good prospects for the right man with ability and initiative. Pension scheme and canteen facilities available.—Apply in writing, giving full details of age, experience, &c., to Patchett and Co., Limited, Westland Road, Leeds, 11.

E9852 A

G. & J. WEIR LTD.,

ENGINEERS

CATHCART, GLASGOW, S. 4.

Have vacancy for an ASSISTANT in the Research Department. Applicants should have a degree in Physics or Electrical Engineering or equivalent qualifications. Duties will involve investigation into causes of noise and vibration, and electronic measurement. Applications, stating age, experience, education and qualifications should be addressed to Personnel Manager.

E9877 A

BUILDING INDUSTRY

SPECIALIST SUB-CONTRACT SUPERVISOR

A major firm of Building and Civil Engineering Contractors in Northern England require an experienced ENGINEER/SUPERVISOR for specialist sub-contracts. He will be the Liaison Officer between themselves as Main Contractors and the numerous sub-contractors carrying out the mechanical and industrial services on large projects.

Applicants should preferably be qualified, be good organisers and have considerable experience in design and installation contract work, using up-to-date methods of planning and progressing.

Good prospects and staff conditions, pension scheme and other benefits.

Apply Managing Director, BOX No. E9910, "The Engineer."

A

SENIOR ENGINEER

Large Textile Company in the West Riding of Yorkshire with number of branch factories requires SENIOR ENGINEER. The successful applicant will initially be responsible to the Chief Engineer with a view to ultimate appointment to that position. Applicants must be capable of assuming full control and have had considerable experience in operation and maintenance of varying types of power plants, including reciprocating engines and back pressure turbo-alternators and chain grate and sprinkler type stokers. Knowledge of electrical generating and motive plant also necessary. Applicants should have University degree (Honours Standard advantageous) together with practical and organising ability. Some Commercial knowledge an asset. Age about 40–45. The position is a senior and responsible one with correspondingly substantial remuneration and superannuation.—Applications which will be treated in strict confidence to be sent with full particulars of experience and previous career to BOX No. E9785, "The Engineer."

MSL have been retained to advise on the appointment of a

SALES CONTROLLER (Constructional Steelwork)

for a constructional engineering company in Northern England with a turnover of approximately £2 million.

Sales control has been exercised by the present members of the Board, but there is now an opportunity for a Sales Controller to join the company and assist in its further expansion. He will advise the Board on sales policy, control the sales organisation for direct representatives and agents and negotiate with principal customers.

Commencing salary £2,000 or more for relevant experience, plus other benefits including car, superannuation and assistance with re-housing.

Candidates aged 35–45, should be qualified civil or structural engineers with sales experience in the steel construction industry.

No information will be disclosed to our clients until candidates know their identity and have given permission after personal discussion. Please send brief details in confidence, quoting reference G.1483, to W. F. Younger.

MANAGEMENT SELECTION LIMITED

17, Stratton Street, London, W.1.

E134 A

Applications are invited from men between 25 and 32 years of age for the position of :

ASSISTANT TO THE MECHANICAL ENGINEER

at an integrated iron and steelworks in North Lincolnshire, where considerable development is taking place.

Applicants should be experienced in general mechanical engineering ; steelworks experience would be an advantage. They should hold a H.N.C. in Mechanical Engineering, graduate membership of the Institution of Mechanical Engineers or similar qualifications. Experience of the human problems involved in steelworks maintenance and knowledge of trade union practice would be helpful.

Salary will depend upon experience and qualifications. A good contributory pension scheme is in operation.

Application forms are available from :

The Personnel Officer,
RICHARD THOMAS & BALDWINS, LTD.,
Redbourn Works, Scunthorpe, Lincolnshire.

E9824 A

ENGLISH ELECTRIC

ATOMIC POWER DIVISION

Whetstone, Near Leicester.
A vacancy has arisen for a

SENIOR MECHANICAL ENGINEER

to deal with problems in Fluid Flow and Heat Transfer associated with the design of pressure systems.

This appointment carries a considerable responsibility, and an ability to conduct discussions with clients and sub-contractors is a requirement. Applicants should be graduate engineers with Corporate Membership of a Senior Institution. Some knowledge of Pressure Vessel practice and standard codes would be valuable.

A vacancy also exists for a

MECHANICAL ENGINEER

to undertake work on the design and specification of the reactor gas circuit and its associated components.

Applications are invited from graduate engineers having a real interest in Thermodynamics, Heat Transfer and Gas Dynamics. Some experience in the field of turbo machinery would be an advantage.

Please write giving details of qualifications and experience to Dept. C.P.S., Marconi House, 336/7, Strand, W.C.2, quoting reference E1817F.

E9878 A

Classified Advts. continued on page 112

SITUATIONS VACANT

The world's leading inventors and manufacturers of special purpose precision machinery for the Tobacco Industry have opening in their London Drawing Office for :—

ELECTRICAL ENGINEER

Desirable applicant should be aged 25–40, with technical qualifications at least up to H.N.C. level and with a broad background of experience in the design and application of electrical and electro-mechanical equipment to precision machinery.

This opportunity is permanent and progressive ; it offers immediate pensionable staff position with 3 weeks' Annual holiday and attractive commencing terms. Applications, stating age, qualifications and experience, should be personally addressed in confidence to G. B. Salmon,

MOLINS MACHINE CO., LTD., Evelyn Street, London, S.E.8

E9846 A

A Company producing Cold Rolled Spring Steel Strip in the Midlands is consolidating its position and making long-terms plans for the future with the backing of an important Group. This Company seeks a first class

SALES ENGINEER

OR

SALES METALLURGIST

who is capable of selling to and fostering close personal relationships with people at Top Level.

Applicants should be aged 30–50, have had a good education, preferably with University training, and be able to show that they have had extensive experience of personal selling at Managing Director and Chairman level. They should have a good Engineering/Metallurgical background and be people of standing. Experience in the field of Cold Rolled Spring Steel is desirable, but not essential.

The prospects of the post offered are excellent and the salary substantial.

Applications, giving age, present salary and full details of experience and qualifications should be addressed to the Managing Director, BOX No. E9859, " The Engineer."

A

RESEARCH ENGINEERS

with Honours Degrees and preferably research experience, required for three posts to be concerned with

High-pressure turbo-charging Combustion
Vibration and Noise

in the further development of diesel engines.

Salaries up to £1600 a year, according to qualifications and experience. Pension scheme.

Please apply in writing, giving age, education, training and experience, to :

Director of Research,
The British Internal Combustion Engine Research Association,
111–112, Buckingham Avenue,
Slough, Bucks.

E9843 A

THE BAHRAIN PETROLEUM COMPANY LIMITED
GRADUATE METALLURGISTS & MECHANICAL ENGINEERS

are required in Bahrain's modern Oil Refinery for plant and corrosion inspection work. Applicants, under 35, should be familiar with API, ASME codes and have had a minimum of two years' experience in similar work or in the construction and maintenance of fired and unfired pressure vessels, the duties including inspection of vessels, exchangers, pumps, lines, valves, &c., to ensure safe operating condition and the recommending and developing of materials and methods of repair and corrosion control.

Salary would be in accordance with qualifications and experience but not less than £1332 per annum in addition to which free air conditioned accommodation and a living allowance are provided. An initial kit allowance, medical attention, paid local and home leaves are also provided.—Apply in writing with full particulars to Caltex Services, Ltd., Caltex House, Knightsbridge Green, London, S.W.1, quoting " INS."

E9904 A

SITUATIONS WANTED

COST CONTROLLER/BUDGET OFFICER, qualified, experienced standard costs, budgetary control, management accounts. Seeks responsible position. Available immediately.—BOX No. E2295, " The Engineer." B

BUSINESSES and PREMISES

HAINAULT, ESSEX.—18,500 sq. ft., site area 2·6 acres. Newly erected Single-Storey Factory, with adjoining canteen building and attractive two-storey front office block. Factory headroom 17ft 6in. Clear space. Central heating. Extensive concrete yard and forecourt. Land for expansion. Lease 80 years. Ground rent £520 p.a. Price £50,000.—CHAMBERLAIN AND WILLOWS, 23, Moorgate, E.C.2 (MET 8001). E9868 L

AGENCIES

SALES AGENCY near London seek ONE or TWO ADDITIONAL REPRESENTATIONS in non-conflicting fields, such as Machine Tools, Steel Fabrication, Hydraulic Equipment, Mechanical Handling, &c. Complete coverage by qualified engineers.—BOX No. E2299, " The Engineer." D

SUB-CONTRACTING

CASTINGS.—We can save your porous castings, ferrous or non-ferrous, by an approved impregnation process ; sample castings treated ; A.I.D. approved. —Recupero, Ltd., 66, South Harrow Viaduct, Harrow, Middlesex ('Phone, Byron 1178). E109 MW

KELLERING AND CAM PROFILING capacity up to 8ft. by 6ft. or 6ft. diameter.—ARMYTAGE BROS. (KNOTTINGLEY), Ltd., The Foundry, Knottingley, Yorkshire (Telephone : Knottingley 2743/4). E116 MW

PATENTS

PATENT NO. 710,332.—" Improvements in the Manufacture of Bessemer Steel and Thomas Steel." The Proprietors of Patent No. 710,332 desire to enter into arrangements by way of Licence or otherwise on reasonable terms to ensure its full development and commercial working in this country.—Address inquiries to W. P. Thompson and Co., Chartered Patent and Trade Mark Agents, 12, Church Street, Liverpool, 1. E9896 H

FOR HIRE

LATTICE STEEL. Erection Masts (light and heavy), 30ft. to 150ft. high, for immediate hire.—Bellman's, 21, Hobart House, Grosvenor Place, S.W.1 ('Phone, SLOane 5259). E103 K

MACHINERY Etc. WANTED

WANTED, Arc Melting Furnace, Birlec Electromelt or similar, 2 to 4 tons capacity, with transformers and switchgear.—The Brockmoor Foundry Co., Ltd., Brockmoor, Brierley Hill, Staffs (Tel.: Brierley Hill 77026). E2277 F

WANTED, MODERN NO. 2I COCHRAN VERTICAL BOILER, 105 p.s.i., with fittings and extended skirt.—BOX No. E9786, " The Engineer." F

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HYDRAULIC PRESSES

3000-ton PLATE FORMING AND BENDING PRESS, table 16ft. by 4ft. 6in., admits 10ft. 6in. between columns.
2000-ton HYDRAULIC FORGING PRESS, admits 8ft. 6in. between columns.
1000-ton HYDRAULIC FORGING PRESS by Wellman, admits 6ft. between columns.
LARGE STOCK OF HYDRAULIC PRESSES OF ALL TYPES.

REED BROTHERS (ENGINEERING), LTD.,
REPLANT WORKS,
WOOLWICH INDUSTRIAL ESTATE,
LONDON, S.E.18.
Telephone : Woolwich 7611/6. E9887 G

FOR SALE

SERVICE EDWARDS VALUE!

TAYLOR and CHALLEN No. 3 G.D.P. Geared, Double-Sided, Double-Action, Cam-Action Drawing Press, arranged motor drive for 400/440/3/50, punch stroke approximately 7in., blankholder stroke approximately 3½in., tee slotted bed 18in. by 15½in., between uprights 20½in. Weight approximately 51 cwt.
QUICKWORK No. 321 Motorised, Rotary Shearing Machine, with circle cutting attachment, arranged motor drive for 400/440/3/50, capacity 14 S.W.G. mild steel, depth of shear throat 30in., cuts circles from 6in. to 60in. diameter. Weight approximately 18 cwt.
RHODES Motorised, Double-Geared Press Brake, with cast iron side frames, reinforced by nickel-chrome steel bars, bed and top beam are of steel plate, arranged motor drive for 400/3/50, pressure exerted 150 tons, forming capacity 10ft. by 3/16in. or 18ft. by approximately ¼in., clear width between housings 10ft. 2in. Weight approximately 20 tons.
NEW MUBEA Model KSG100 All-Steel Construction Bar and Angle Shear. The flywheel is situated inside the body. Arranged motor drive suitable for 400/3/50. Capacity : round bars 2in.; square bars 2in.; flat iron 10in. by ½in., 5½in. by 1in.; angles up to 4in. by ½in., 5in. by 0·425in.; tee iron 5in.; beams 6in.; channels 6in.; length of blades 12½in.
TAYLOR and CHALLEN No. 576 Open-Fronted, Inclinable Power Press, with detachable front tie bars, pressure exerted approximately 20 tons, stroke 3in., tee slotted bed 27½in. by 22½in.
INCANDESCENT Forced-Draft Bar Heating Furnace, double ended, gas fitted ; heating chamber 36in. wide by 24in. deep by 9in. high, total length through furnace 32in. working, temperature range 900 deg. to 1350 deg. Cent.; 1200 deg. Cent. can be reached in about 1½ hours after starting from cold.
Photographs of the above are available.
Very favourable Hire Purchase terms can be obtained.

MACHINE TOOLS, NEW AND USED,
Of Every Description. Attractive Prices.

F. J. EDWARDS LTD.,
359–361, EUSTON ROAD,
LONDON, N.W.1.
Telephone : EUSton 4681–3771,
and at
LANSDOWNE HOUSE, 41, WATER STREET,
BIRMINGHAM, 3.
Telephone : Central 7606–8. E207 G

FOR SALE

Seven Murex diesel Welding Sets, 300/400 amp.
Quantity of Guyrex and RMD Shuttering.
Three-tool BroomWade 167 cu. ft. Portable diesel Compressor Set on pneumatics with overrun brakes.
1 cu. yd. Rapier 440 diesel driven Excavator with shovel or dragline equipment.
¾ cu. yd. Rapier 410 diesel-driven Excavator with 4-purpose or dragline equipment.
½ cu. yd. Rapier 423 diesel-driven Excavator with shovel equipment.
5-ton Morris Versatile diesel/elec. Mobile Crane on solid rubber tyres.
5-ton Smith Steam Loco. Crane, 4ft. 8½in. gauge, 35ft. jib, new 1949.
6-ton Rapier Super pet./elec. Mobile Crane on solid rubber tyres.
6-ton Rapier Standard pet./elec. Mobile Crane on solid rubber tyres.
4½ cu. yd. Aveling-Barford diesel-driven Dumper.

WILLIAM G. SEARCH, LIMITED
WHITEHALL ROAD, LEEDS, 12.
Tel. : 639081 (10 lines).
SEARCH (LIVERPOOL), LIMITED
HAMMOND ROAD,
KIRKBY TRADING ESTATE, LIVERPOOL.
Tel. : Simonswood 3361 (5 lines).
E9860 G

GLENFIELD & KENNEDY
NEW CAST IRON SLUICE VALVES
FROM STOCK AT BARGAIN PRICES

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6 8in. bore Fig. A.12 at £23 each.
1 20in. bore Fig. A.2 at £75 each.
3 18in. bore Fig. A.2 at £65 each.
1 15in. bore Fig. A.2 at £50 each.
This is only a small selection of our large and varied stocks.

G. E. SIMM MACHINERY, LTD.,
27, Broomgrove Road, Sheffield, 10.
Tel. : 64436 (5 lines). E9799 G

THREE 30FT. BY 9FT. 9IN. DIAMETER DISH-ENDED PRESSURE TANKS OR RECEIVERS, 13,200 galls., 75 p.s.i. working pressure. AS NEW.
JOSEPH PUGSLEY AND SONS, LTD.,
BRISTOL, 5.
Tel.: Bristol 56037. E9845 G

HYDRAULIC PRESSES
HYDRAULIC PUMPS
Hydraulic Accumulators, Valves, Fittings, New and Second-hand. Complete installations.
All kinds of Hydraulic Equipment in stock.
THOMPSON AND SON (MILLWALL), LTD.
Cuba Street, Millwall, London, E.14.
East 1844/5. E111 G

NISSEN TYPE HUTS for sale. Prompt despatch of 16ft., 24ft. and 30ft. wide huts ; also " Romney " Huts, 35ft. wide, and " Blister " Hangars, 86ft. 6in. and 91ft. wide. These buildings are in various lengths and comprise steel framework with galvanised corrugated steel sheeting.—Full details from Dept. 115, J. Thorn and Sons, Ltd., Brampton Road, Bexleyheath, Kent (Tel. : Bexleyheath 305). E113 G

FOR SALE, Sundry Unused SPARES for 1950 Hopkinson low-ram mechanical stoking gear.—Inspection can be made by appointment with Mr. J. Humphrey, Kemball, Bishop and Co., Ltd., Crown Chemical Works, Three Mill Lane, Bromley-by-Bow, London, E.3. E9903 G

FOR SALE

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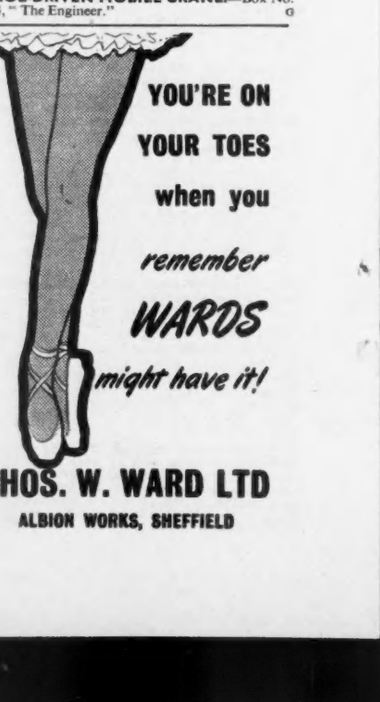

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February 20	Miscellaneous stores, including tool kits, greatcoats, etc.	Returned Stores Group, Reed Hall, Colchester.	FENN, WRIGHT & CO. (Dept. L), 146, High Street, Colchester, Essex. (Tel.: 3171.)
February 24–26	Machine tools, plant and miscellaneous stores, including :— Presses ; polishing headstocks ; generator and charging sets ; pumps ; compressors ; unit heaters ; M.T. spares ; electrical and radio equipment ; air and sand blast units ; spray booths ; ovens ; furnaces ; railway waggons ; steam crane ; steel sheets and bar ; textiles, including clothing, drill, webbing, cotton duck, canvas, scrap blankets and rags ; rope ; furniture ; canteen and kitchen equipment ; watches ; paint ; powders ; chemicals, etc.	M.O.S. Storage Depot, Byley, Nr. Middlewich, Cheshire. (Sale at New Islington Public Hall, Ancoats, Manchester.)	J. H. NORRIS & SON (Dept. L), 9, Albert Square, Manchester, 2. (Tel.: Blackfriars 8373.)
March 3–5	Machine tools and miscellaneous stores.	M.O.S. Storage Depot, Royal Arsenal, Woolwich, S.E.19.	FULLER, HORSEY, SONS & CASSELL (Dept. L), 10, Lloyd's Avenue, London, E.C.3. (Tel.: Royal 4861.)
March 9–10	Miscellaneous stores, including large quantity of vehicle tyres, etc.	M.O.S. Storage Depot, Ruddington, Notts.	WALKER, WALTON & HANSON (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.)
March 12	Office, etc., furniture and racking.	Hawker Aircraft Factory, South Shore, Blackpool.	LESLIE A. BUTSON (Dept. L), 16, Birley Street, Blackpool. (Tel.: 21073.)

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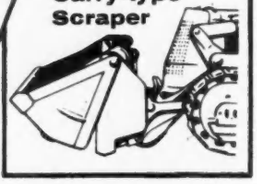

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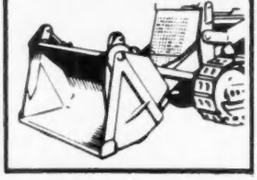

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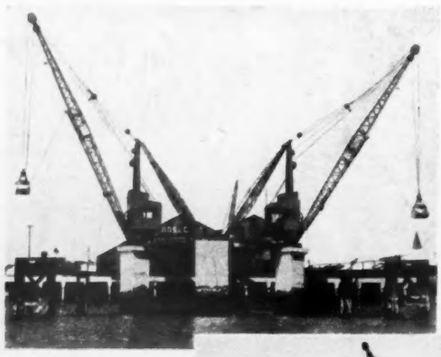

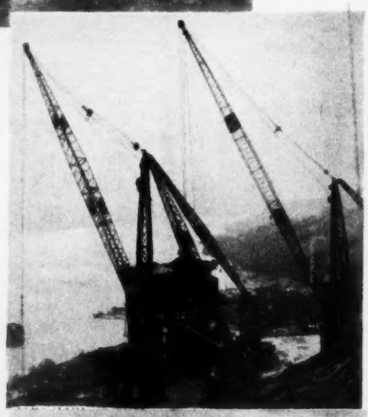

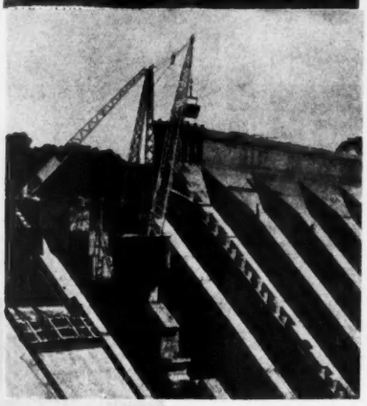

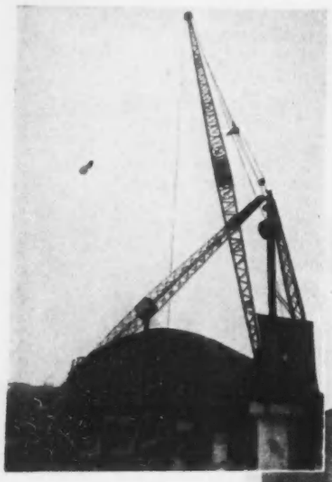

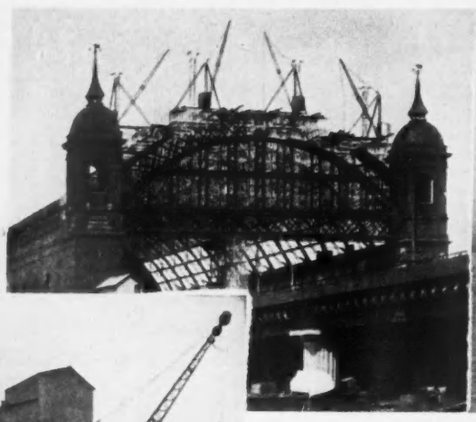

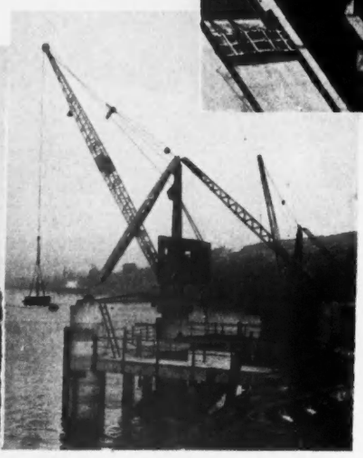

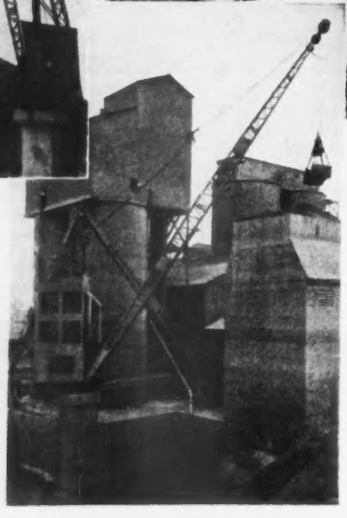

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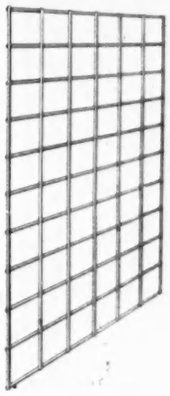

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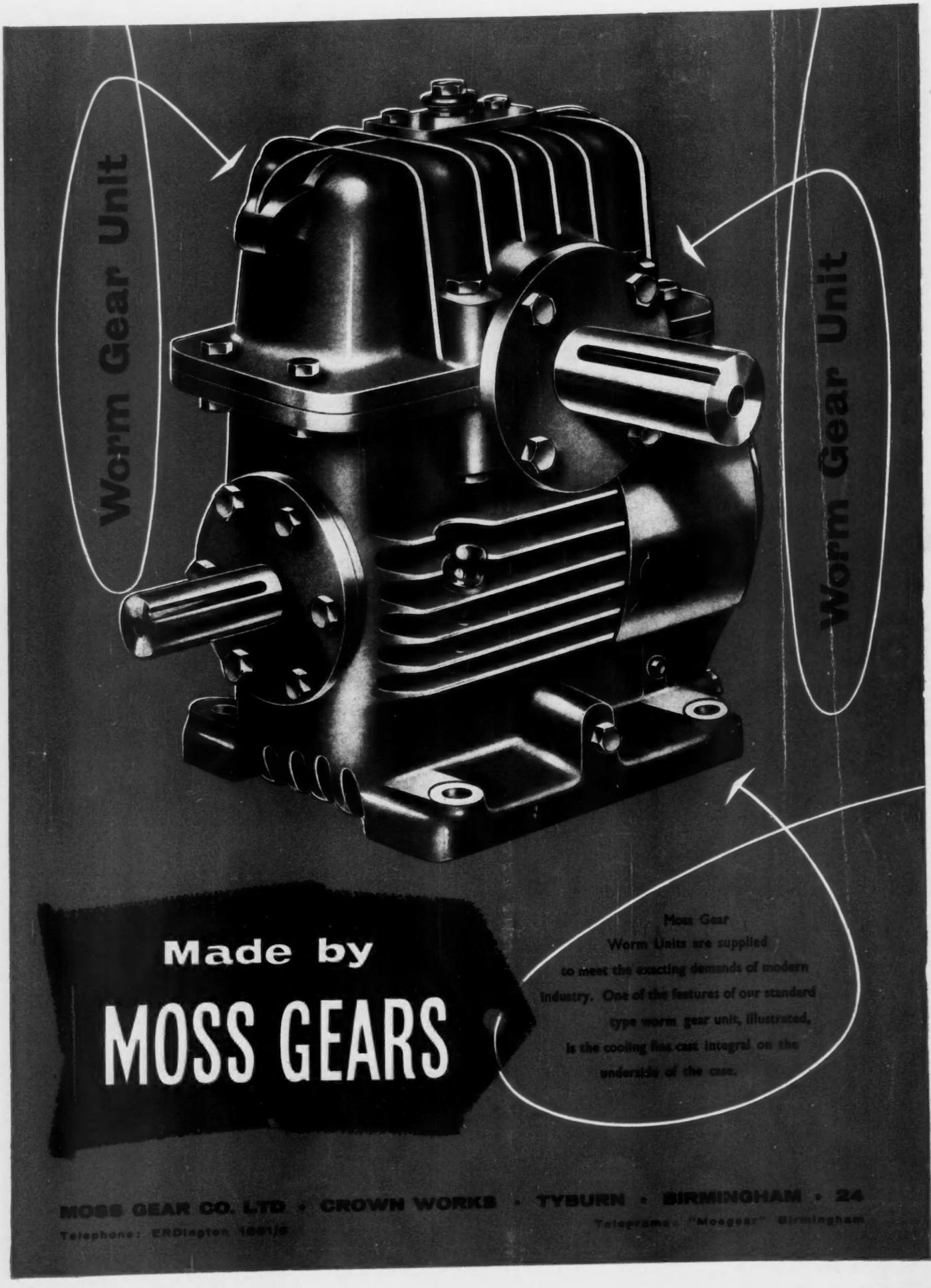
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